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**Baenziger et al.**

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(54) **PATH PERFORMANCE MINI-CHARTS**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 145 days.

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***G06T 11/20*** (2006.01)
***G06T 15/06*** (2011.01)

(52) **U.S. Cl.**
CPC .................................... ***G06T 15/06*** (2013.01)

(58) **Field of Classification Search**
USPC ......................................................... 345/440
See application file for complete search history.

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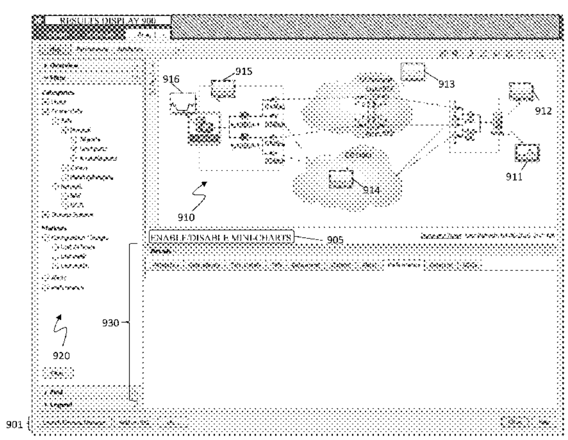
*Primary Examiner* — M Good Johnson
(74) *Attorney, Agent, or Firm* — Muirhead and Saturnelli, LLC

(57) **ABSTRACT**

A system provides for display of results from performance data analysis that presents mini-chart overlays on a topology map based on intelligent analytics for components in a I/O data path of a host or other object. The mini-charts may be advantageously used to show criticality of impact to assist a user with incident avoidance and/or to provide fast incident resolution. When launching into the topology map, the user may enable mini-charts and visually see from the charts where a possible performance bottleneck is detected by the analytics. In an embodiment, the mini-charts for the most relevant metrics may be displayed and identified for criticality, such as by color. The colors may be determined by thresholds, that may be set by a user and/or determined by the system, and may be calculated automatically based on learned base line, maximum line and minimum line operations over set times.

**20 Claims, 20 Drawing Sheets**



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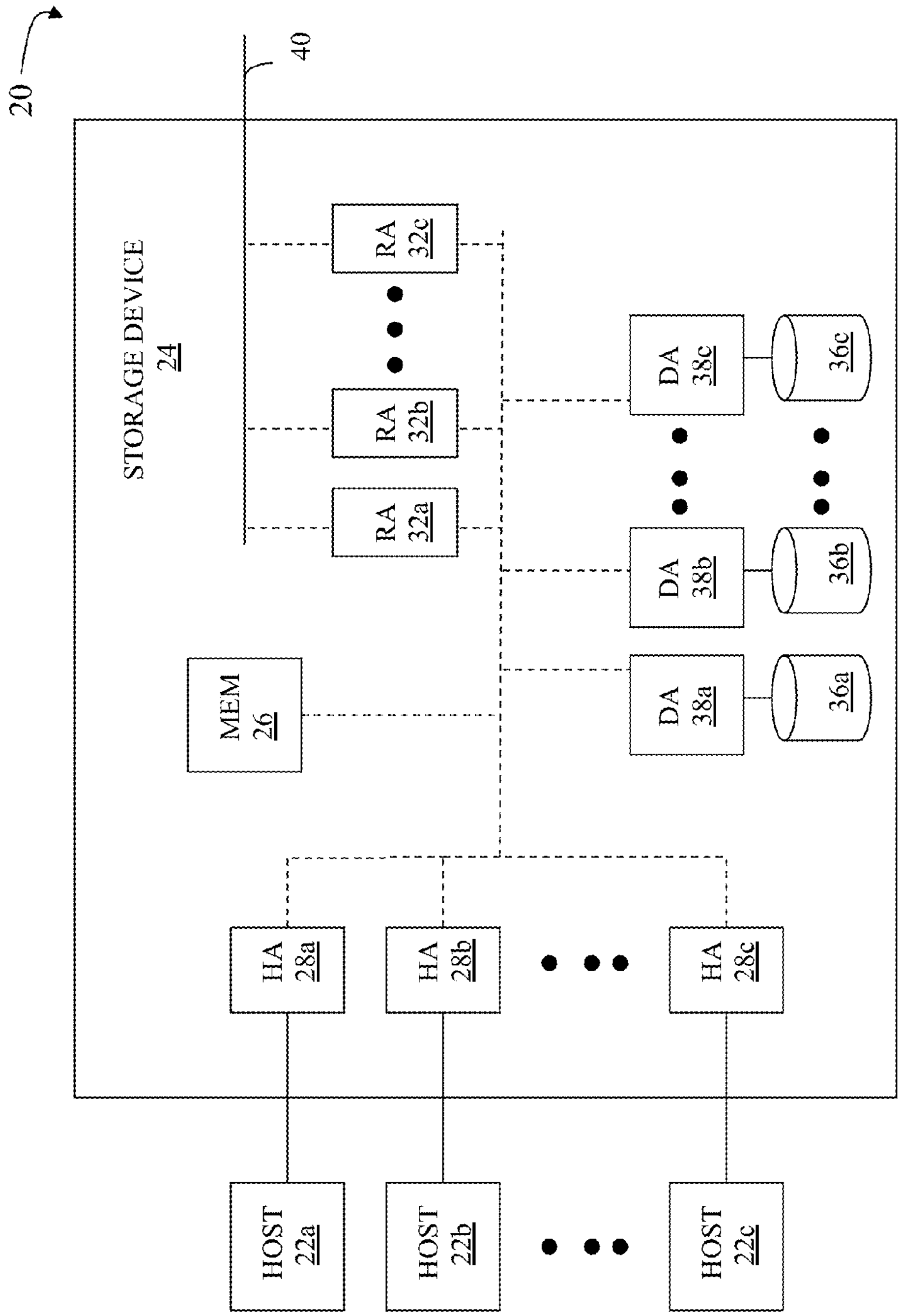

20
40
STORAGE DEVICE
24
RA
32c
RA
32b
RA
32a
MEM
26
DA
38c
DA
38b
DA
38a
36c
36b
36a
HA
28a
HA
28b
HA
28c
HOST
22a
HOST
22b
HOST
22c

FIG. 1

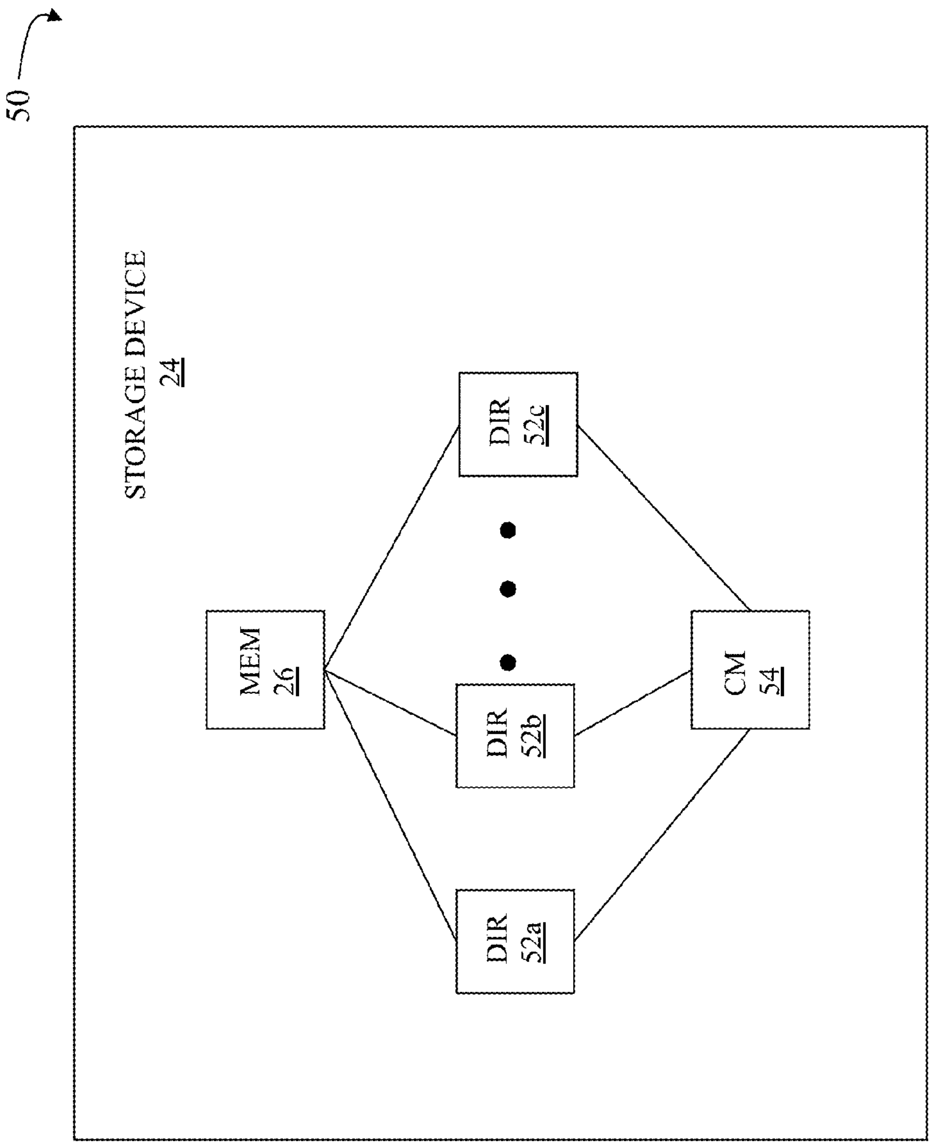



FIG. 2

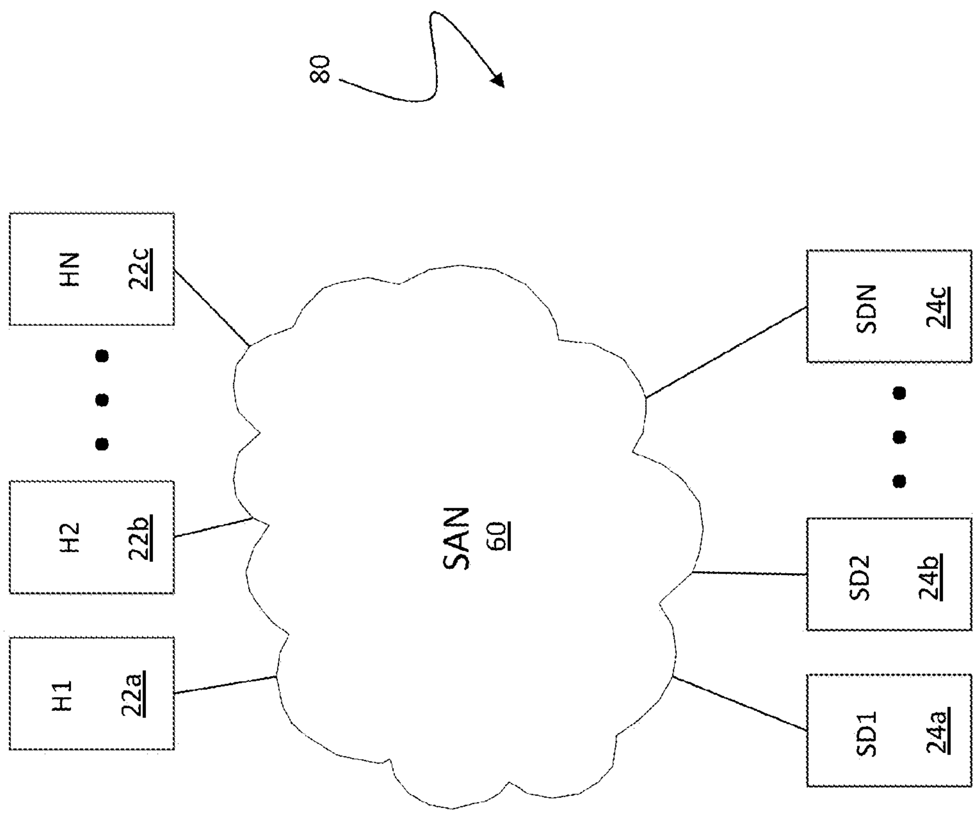



FIG. 3

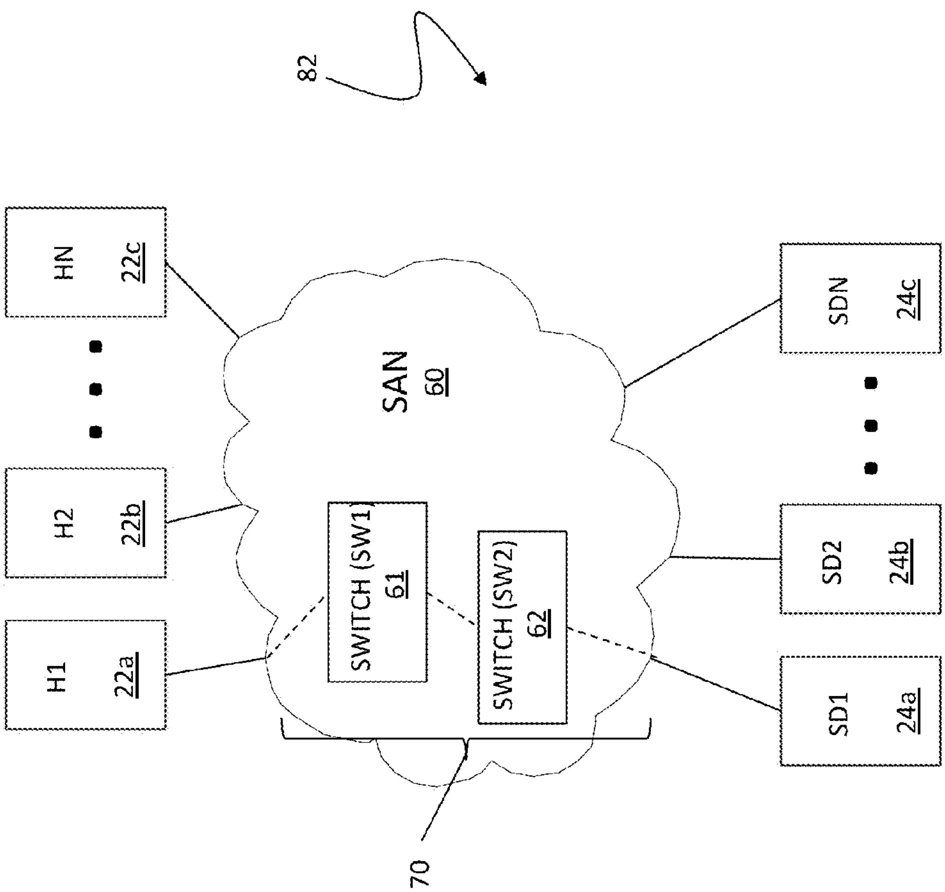

82
H1
22a
H2
22b
HN
22c
SAN
60
SWITCH (SW1)
61
SWITCH (SW2)
62
SD1
24a
SD2
24b
SDN
24c
70

FIG. 4

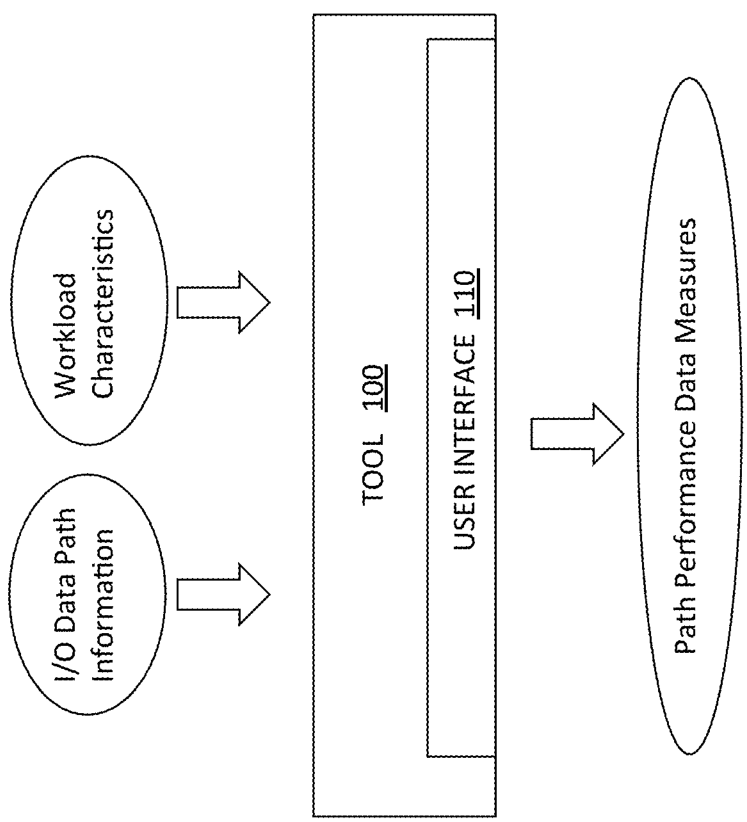

Workload Characteristics
I/O Data Path Information
TOOL 100
USER INTERFACE 110
Path Performance Data Measures

FIG. 5

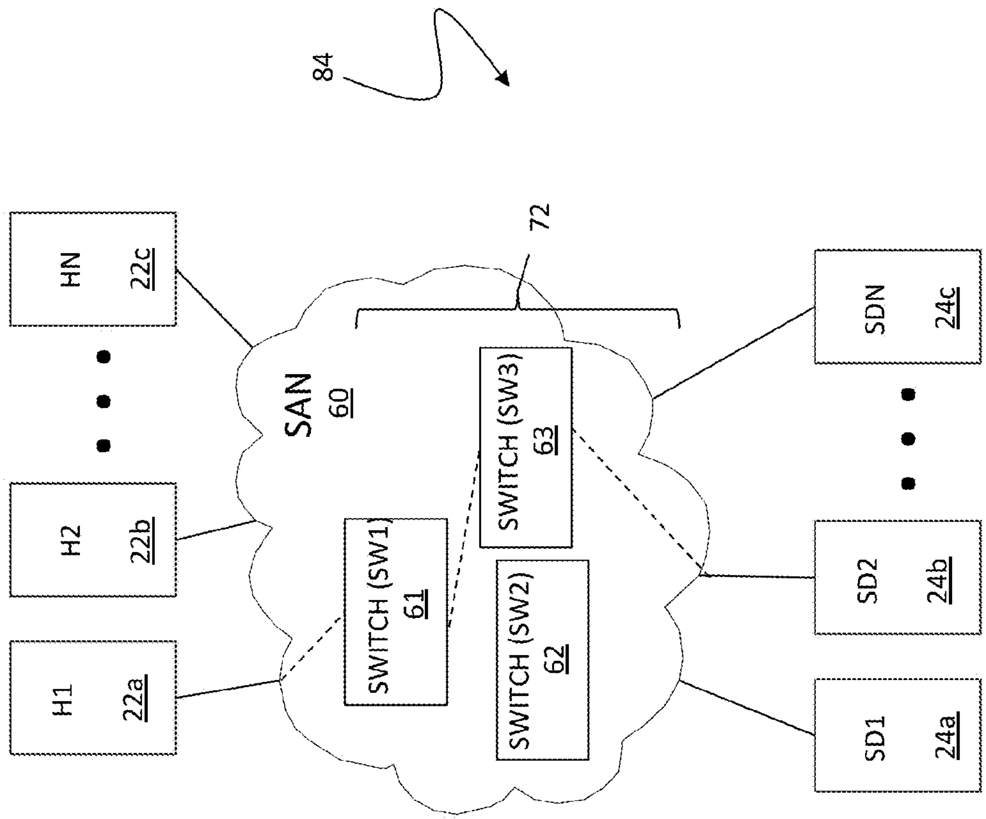

84
72
HN 22c
H2 22b
H1 22a
SAN 60
SWITCH (SW1) 61
SWITCH (SW2) 62
SWITCH (SW3) 63
SDN 24c
SD2 24b
SD1 24a

FIG. 6

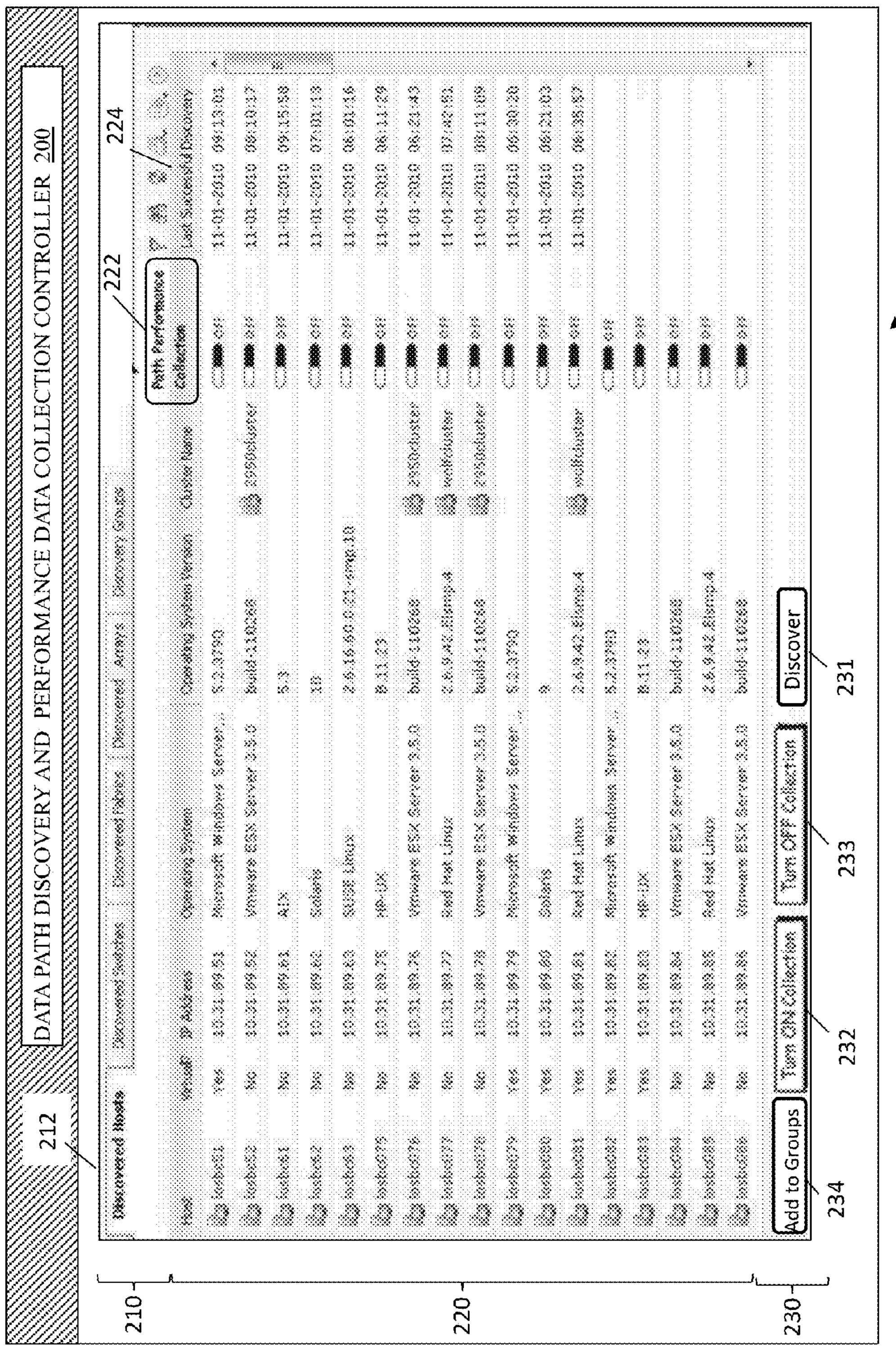

DATA PATH DISCOVERY AND PERFORMANCE DATA COLLECTION CONTROLLER 200
210
212
220
222
224
230
231
232
233
234
Discovered Hosts
Path Performance Collection
Add to Groups
Turn ON Collection
Turn OFF Collection
Discover
110

FIG. 7

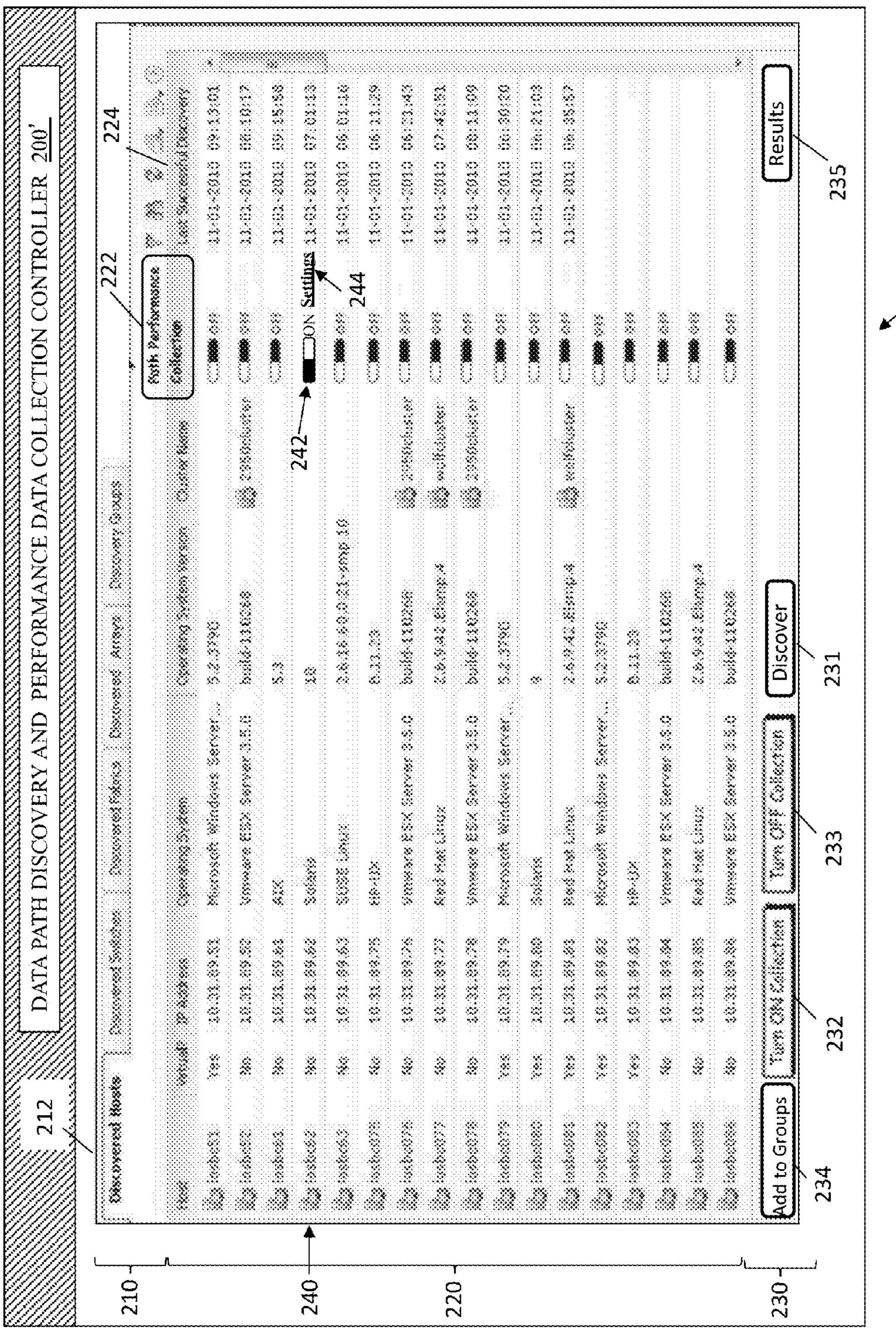

DATA PATH DISCOVERY AND PERFORMANCE DATA COLLECTION CONTROLLER 200'
212
222
224
242
244
Settings
Add to Groups
Turn ON Collection
Turn OFF Collection
Discover
Results
231
232
233
234
235
210
240
220
230
110

FIG. 8

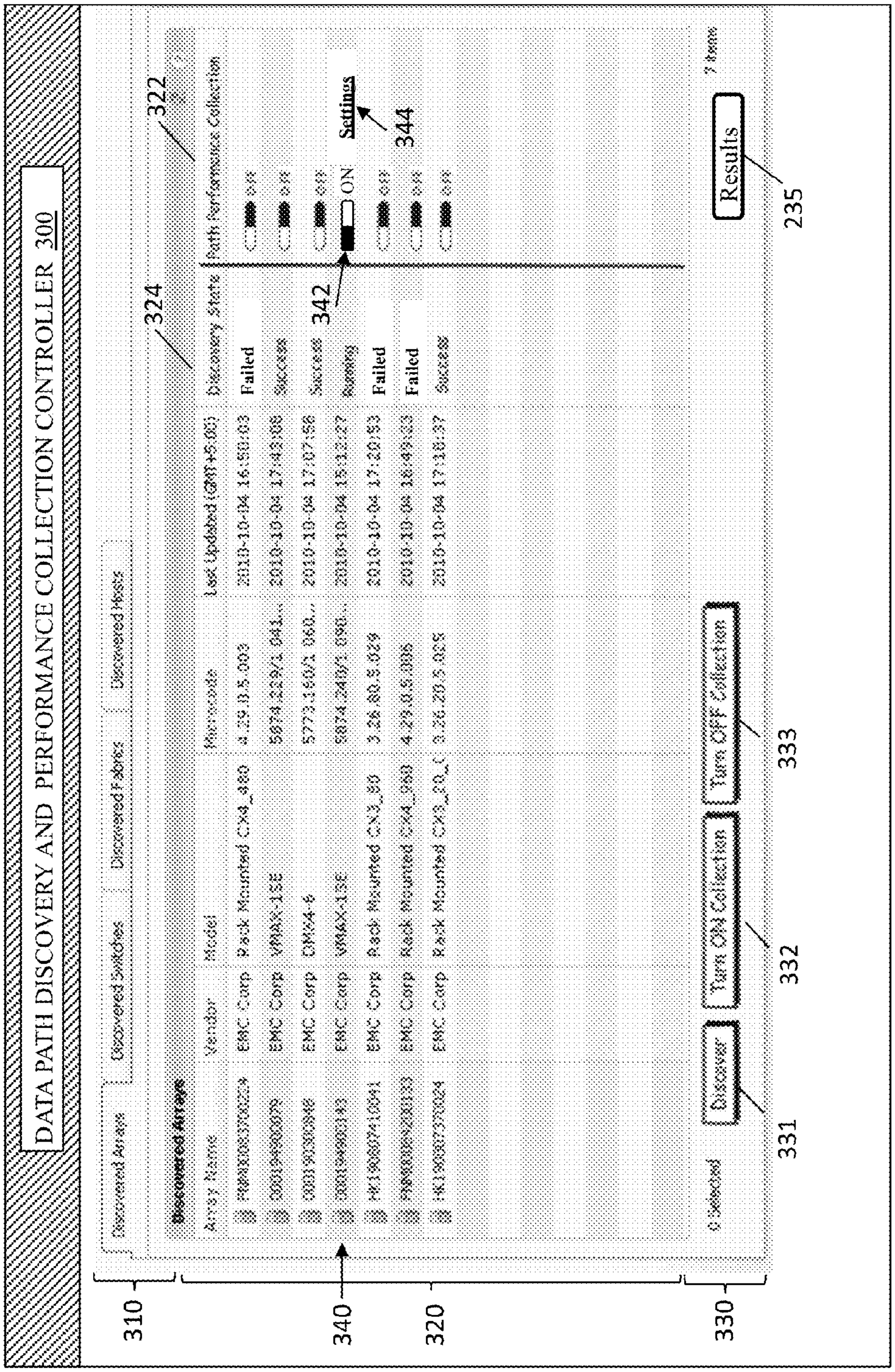

DATA PATH DISCOVERY AND PERFORMANCE COLLECTION CONTROLLER 300
Discovered Arrays
Discovered Switches
Discovered Fabrics
Discovered Hosts
Array Name
Vendor
Model
Microcode
Last Updated
Discovery State
Path Performance Collection
Failed
Success
Running
ON
Settings
Discover
Turn ON Collection
Turn OFF Collection
Results
0 Selected
7 items
310
320
322
324
330
331
332
333
340
342
344
235
110

FIG. 9

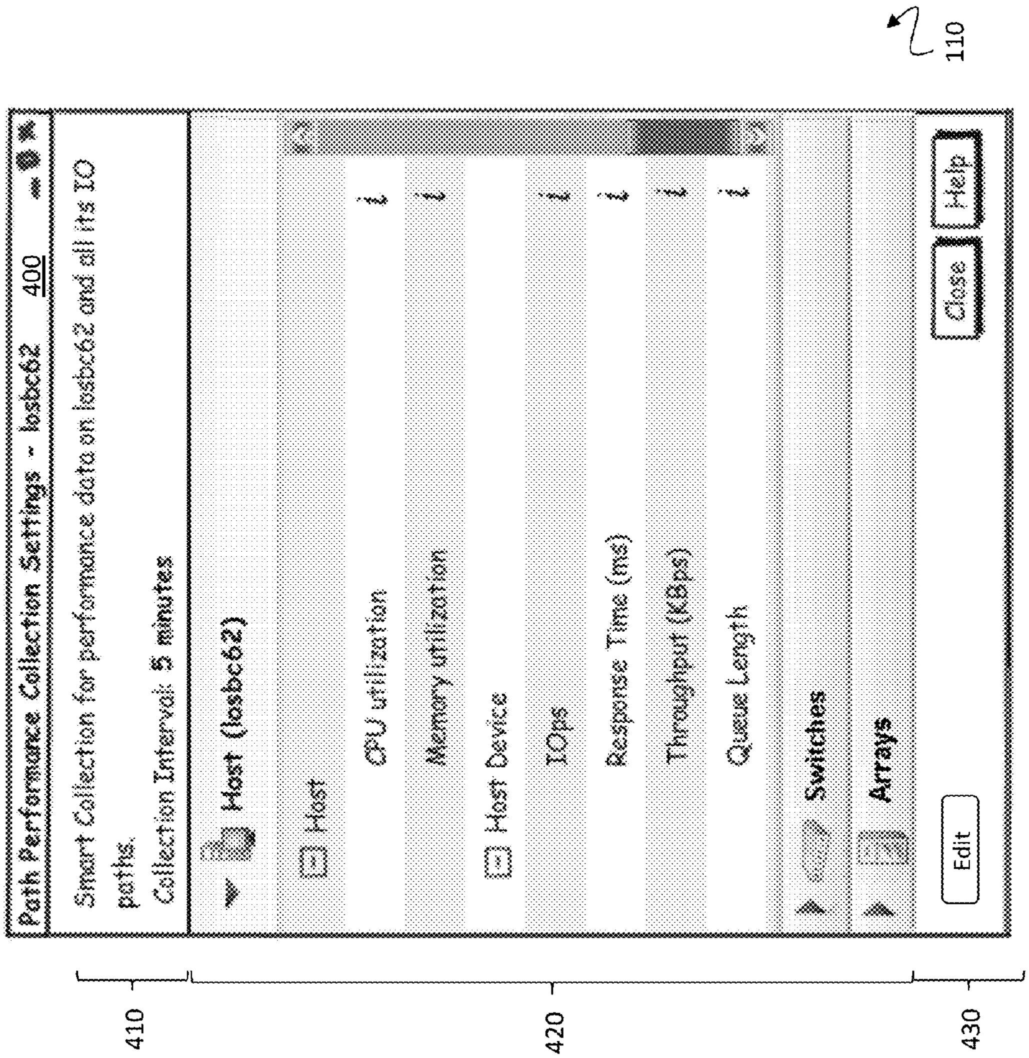
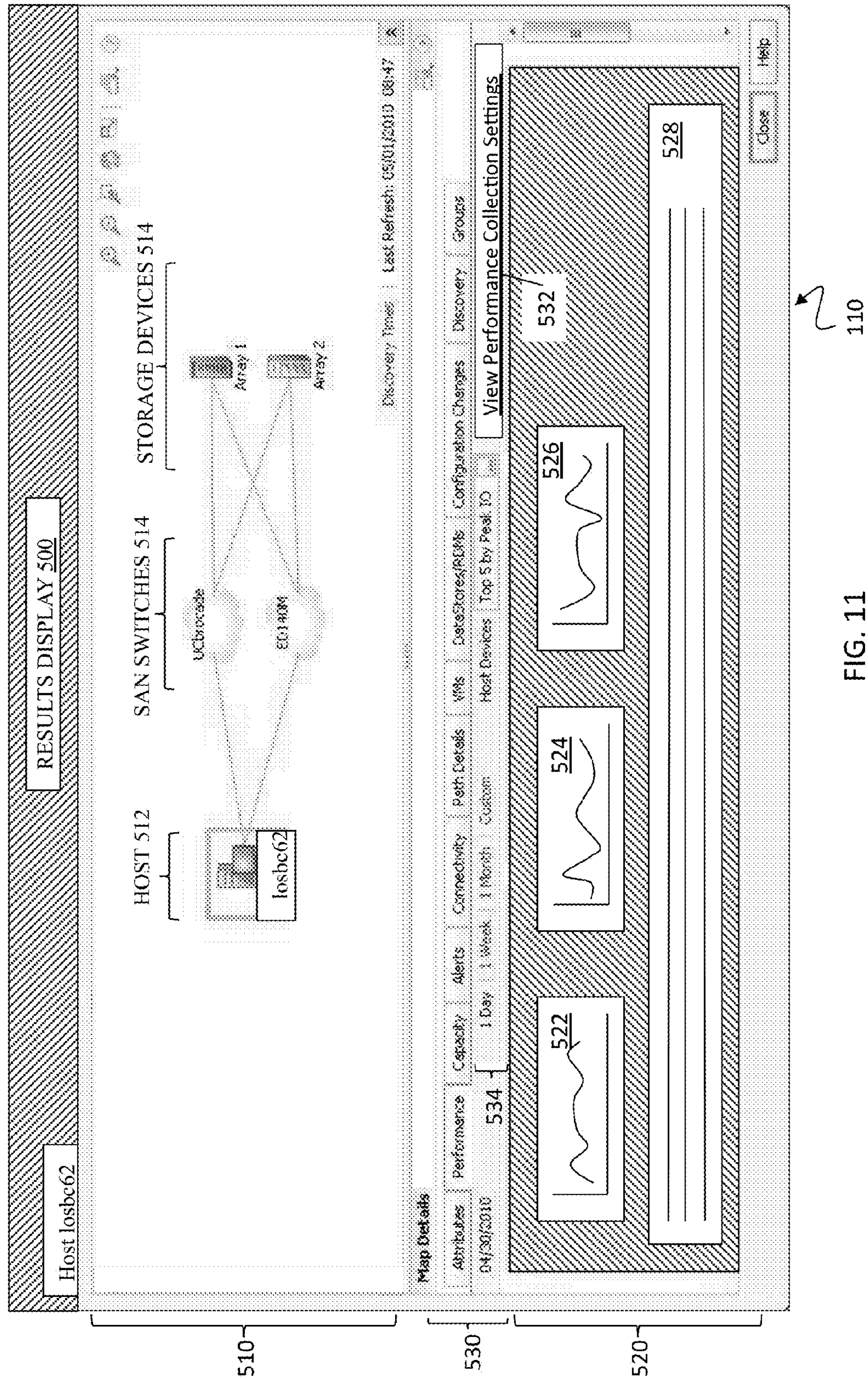

110
Path Performance Collection Settings - losbc62
400
Smart Collection for performance data on losbc62 and all its IO paths.
Collection Interval: 5 minutes
Host (losbc62)
Host
CPU utilization
Memory utilization
Host Device
IOps
Response Time (ms)
Throughput (KBps)
Queue Length
Switches
Arrays
Edit
Close
Help
410
420
430

FIG. 10



RESULTS DISPLAY 500
Host losbc62
HOST 512
SAN SWITCHES 514
STORAGE DEVICES 514
losbc62
Array 1
Array 2
Map Details
Attributes
Performance
Capacity
Alerts
Connectivity
Path Details
VMs
DataStores/RDMs
Configuration Changes
Discovery
Groups
1 Day
1 Week
1 Month
Custom
Host Devices
Top 5 by Peak IO
View Performance Collection Settings
Close
Help
522
524
526
528
532
534
510
530
520
110


FIG. 11

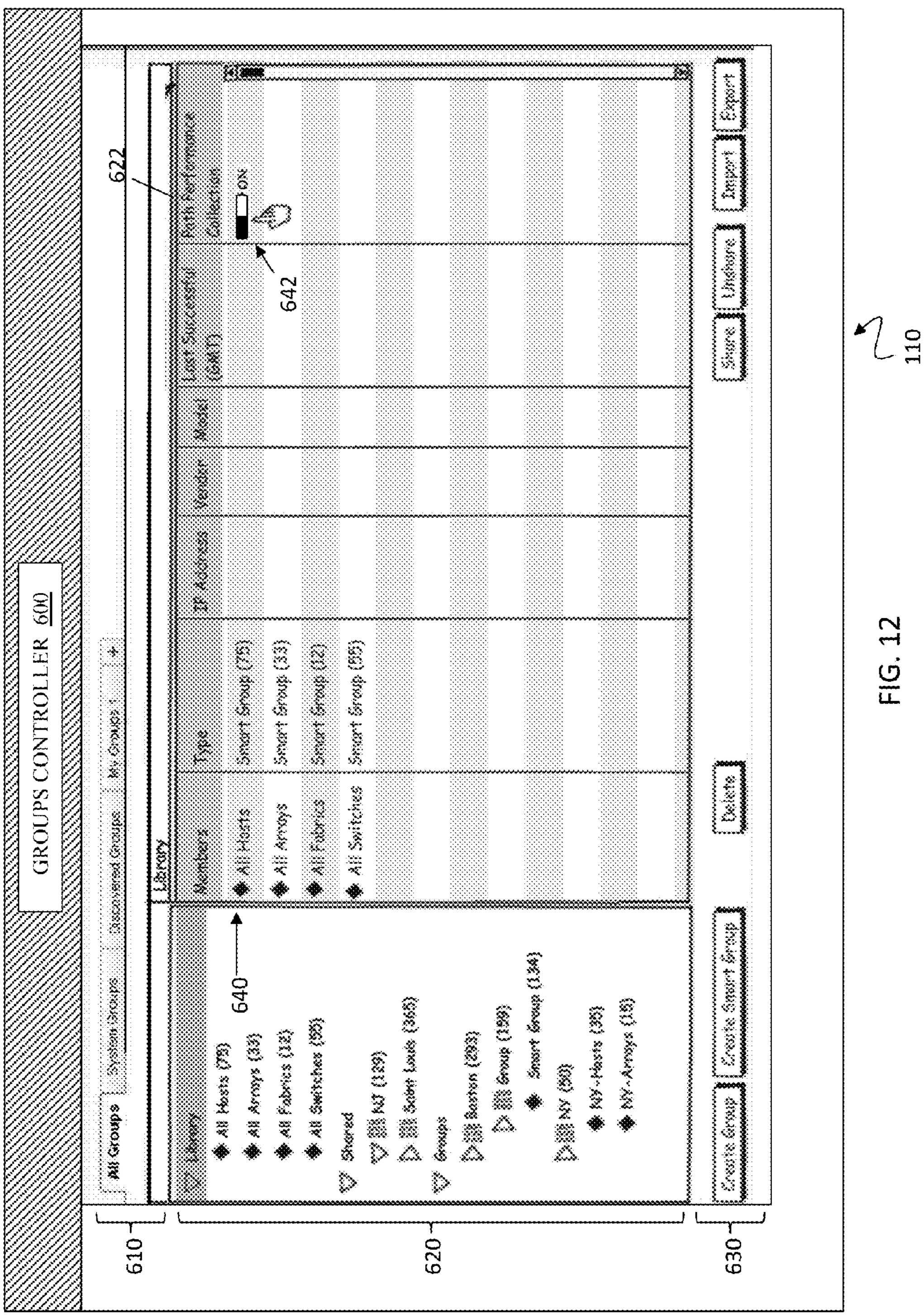

GROUPS CONTROLLER 600
All Groups
System Groups
Discovered Groups
My Groups 1
Library
All Hosts (75)
All Arrays (33)
All Fabrics (12)
All Switches (55)
Shared
NJ (129)
Saint Louis (365)
Groups
Boston (293)
Group (159)
Smart Group (134)
NY (50)
NY-Hosts (35)
NY-Arrays (15)
Members
All Hosts
All Arrays
All Fabrics
All Switches
Type
Smart Group (75)
Smart Group (33)
Smart Group (12)
Smart Group (55)
IP Address
Vendor
Model
Last Successful (GMT)
Path Performance Collection
ON
Create Group
Create Smart Group
Delete
Share
Unshare
Import
Export
610
620
630
622
640
642
110

FIG. 12

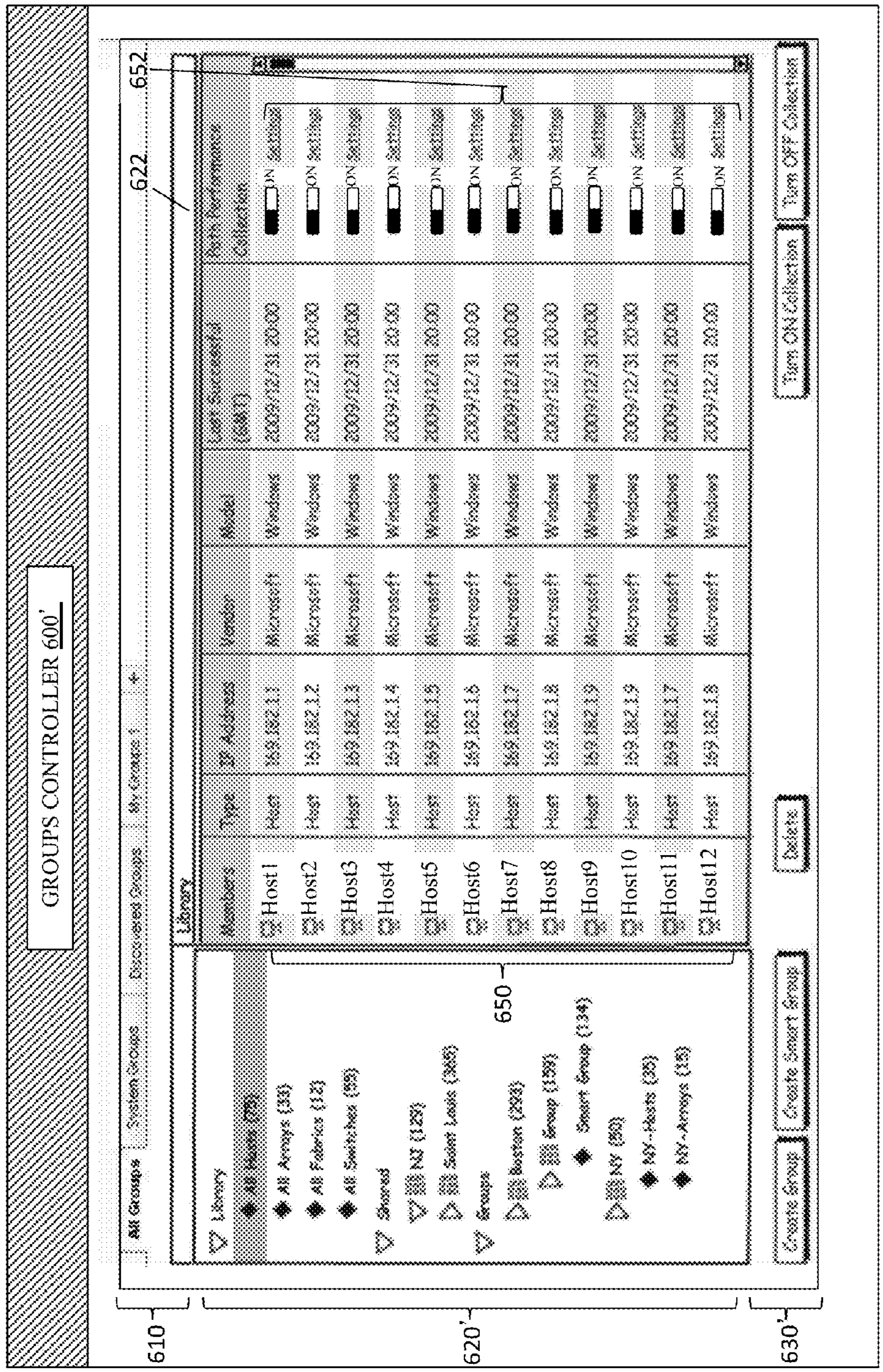

GROUPS CONTROLLER 600'
610
620'
630'
622
650
652
All Groups
System Groups
Discovered Groups
My Groups 1
Library
Members
Type
IP Address
Vendor
Model
Last Successful
Perf Performance Collection
Host1
Host2
Host3
Host4
Host5
Host6
Host7
Host8
Host9
Host10
Host11
Host12
Host
Microsoft
Windows
2009/12/31 20:00
ON
Settings
Create Group
Create Smart Group
Delete
Turn ON Collection
Turn OFF Collection
110

FIG. 13

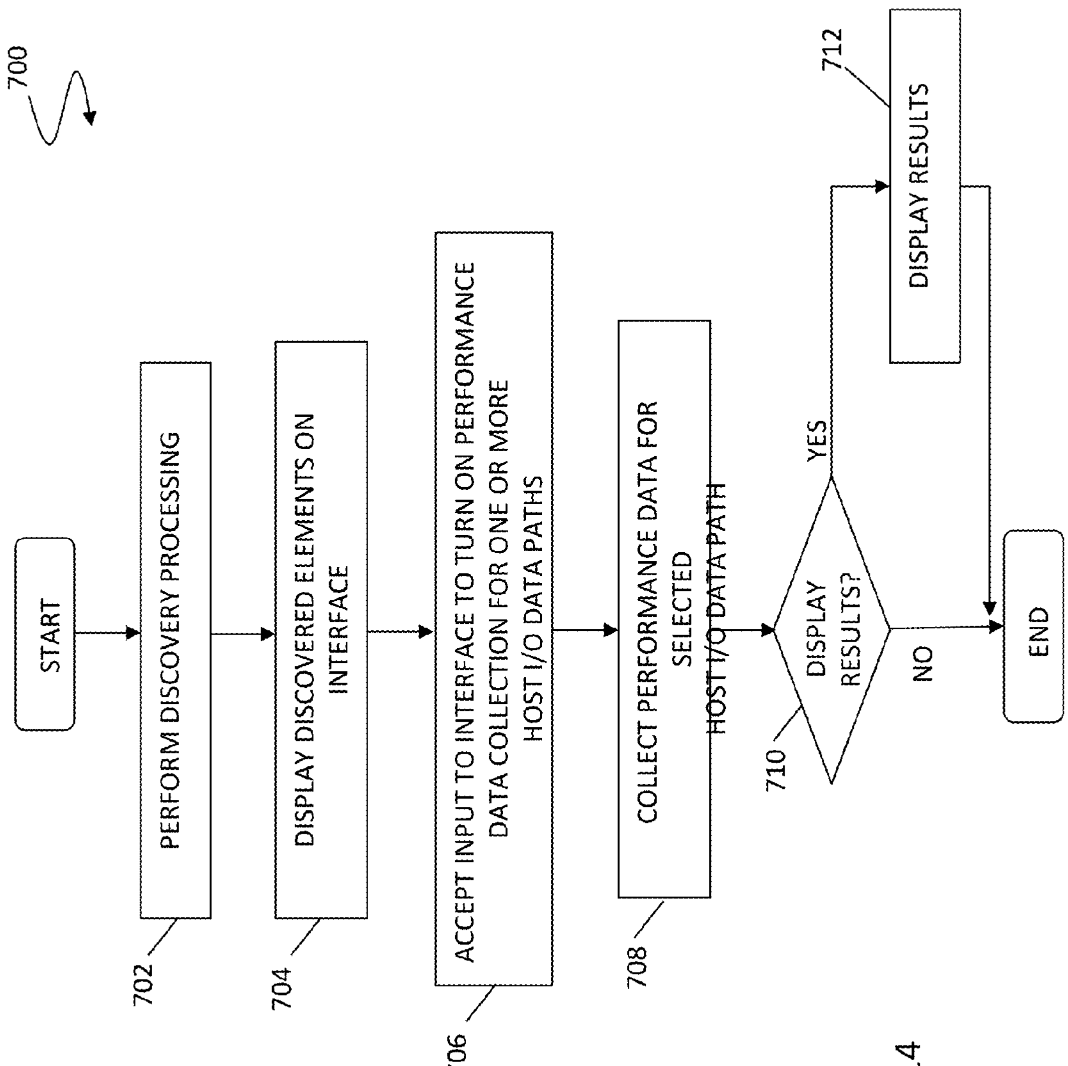

700
START
PERFORM DISCOVERY PROCESSING
702
DISPLAY DISCOVERED ELEMENTS ON INTERFACE
704
ACCEPT INPUT TO INTERFACE TO TURN ON PERFORMANCE DATA COLLECTION FOR ONE OR MORE HOST I/O DATA PATHS
706
COLLECT PERFORMANCE DATA FOR SELECTED HOST I/O DATA PATH
708
DISPLAY RESULTS?
710
YES
NO
DISPLAY RESULTS
712
END

FIG. 14

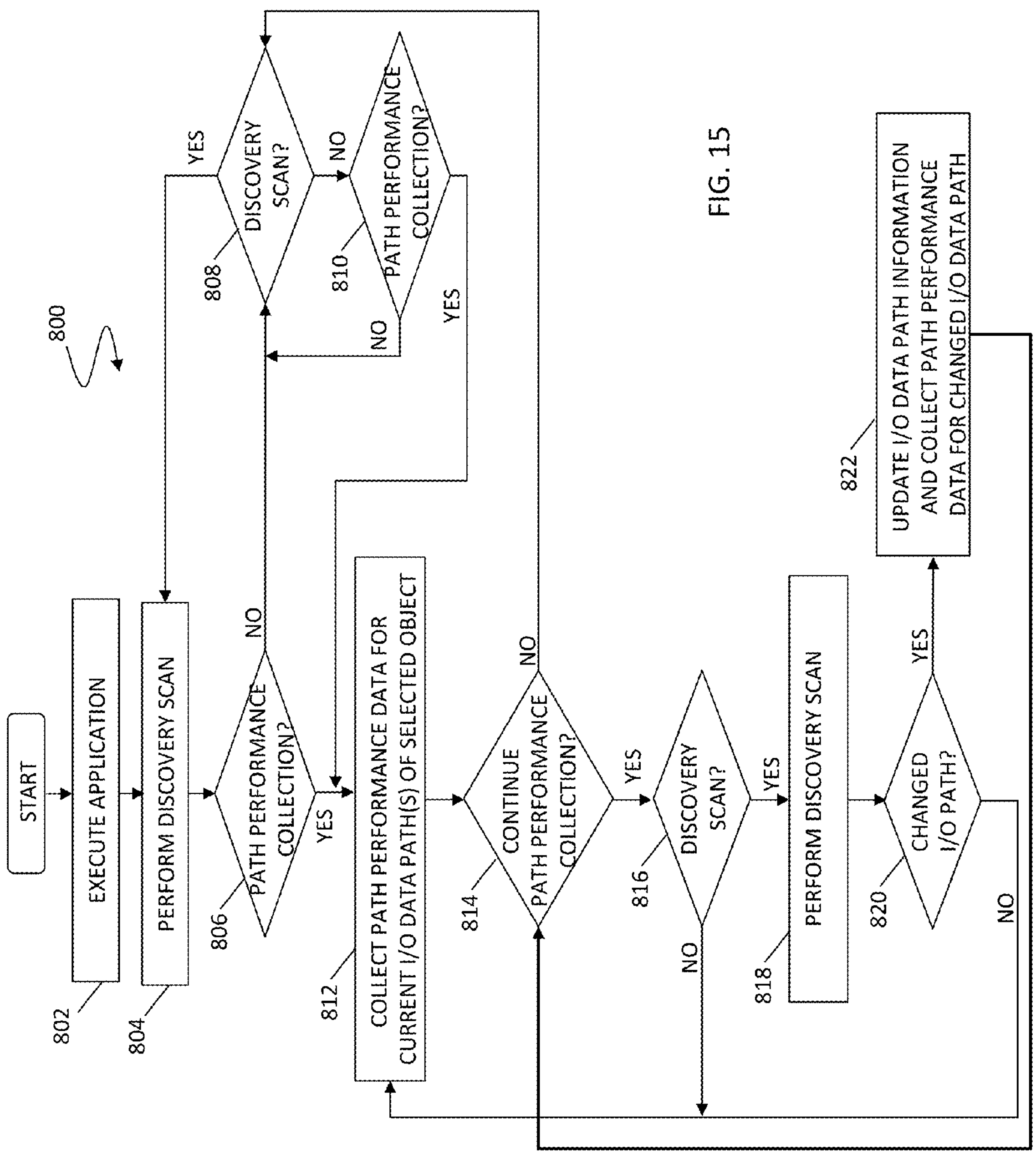

800
START
802
EXECUTE APPLICATION
804
PERFORM DISCOVERY SCAN
806
PATH PERFORMANCE COLLECTION?
YES
NO
808
DISCOVERY SCAN?
YES
NO
810
PATH PERFORMANCE COLLECTION?
YES
NO
812
COLLECT PATH PERFORMANCE DATA FOR CURRENT I/O DATA PATH(S) OF SELECTED OBJECT
814
CONTINUE PATH PERFORMANCE COLLECTION?
YES
NO
816
DISCOVERY SCAN?
YES
NO
818
PERFORM DISCOVERY SCAN
820
CHANGED I/O PATH?
YES
NO
822
UPDATE I/O DATA PATH INFORMATION AND COLLECT PATH PERFORMANCE DATA FOR CHANGED I/O DATA PATH

FIG. 15

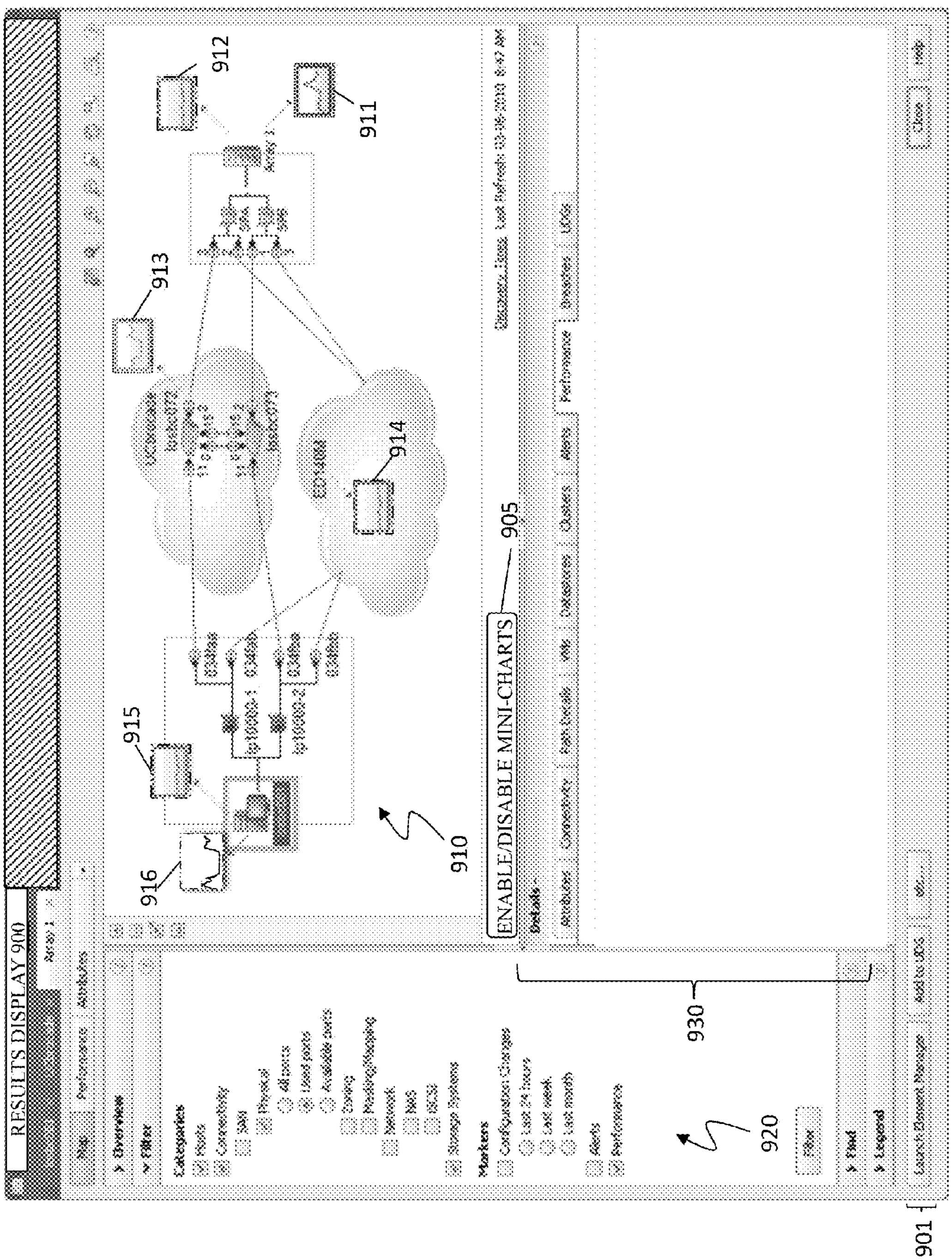

RESULTS DISPLAY 900
ENABLE/DISABLE MINI-CHARTS
901
905
910
911
912
913
914
915
916
920
930

FIG. 16

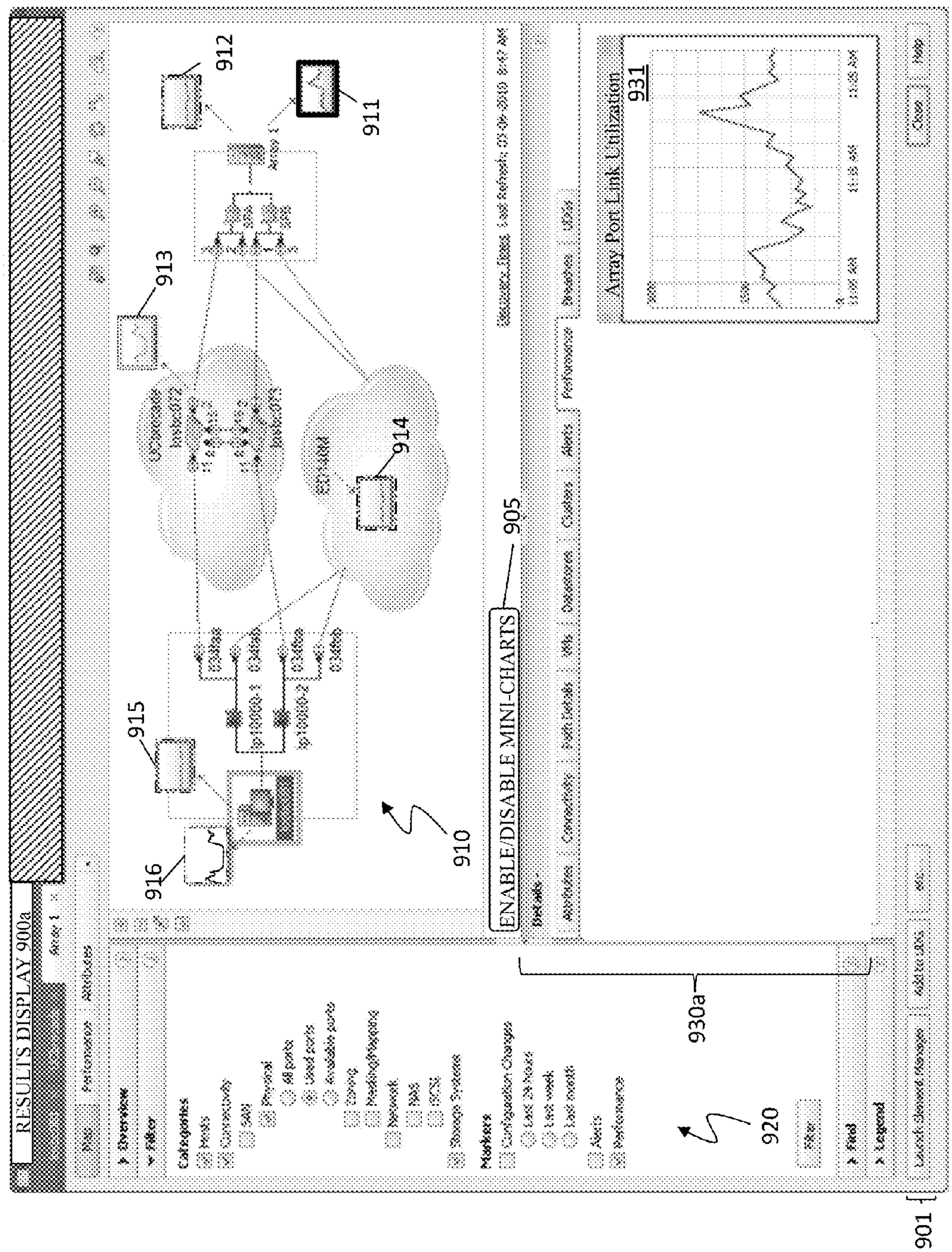

RESULTS DISPLAY 900a
912
911
913
914
915
916
910
905
ENABLE/DISABLE MINI-CHARTS
Array Port Link Utilization
931
930a
920
901

FIG. 17

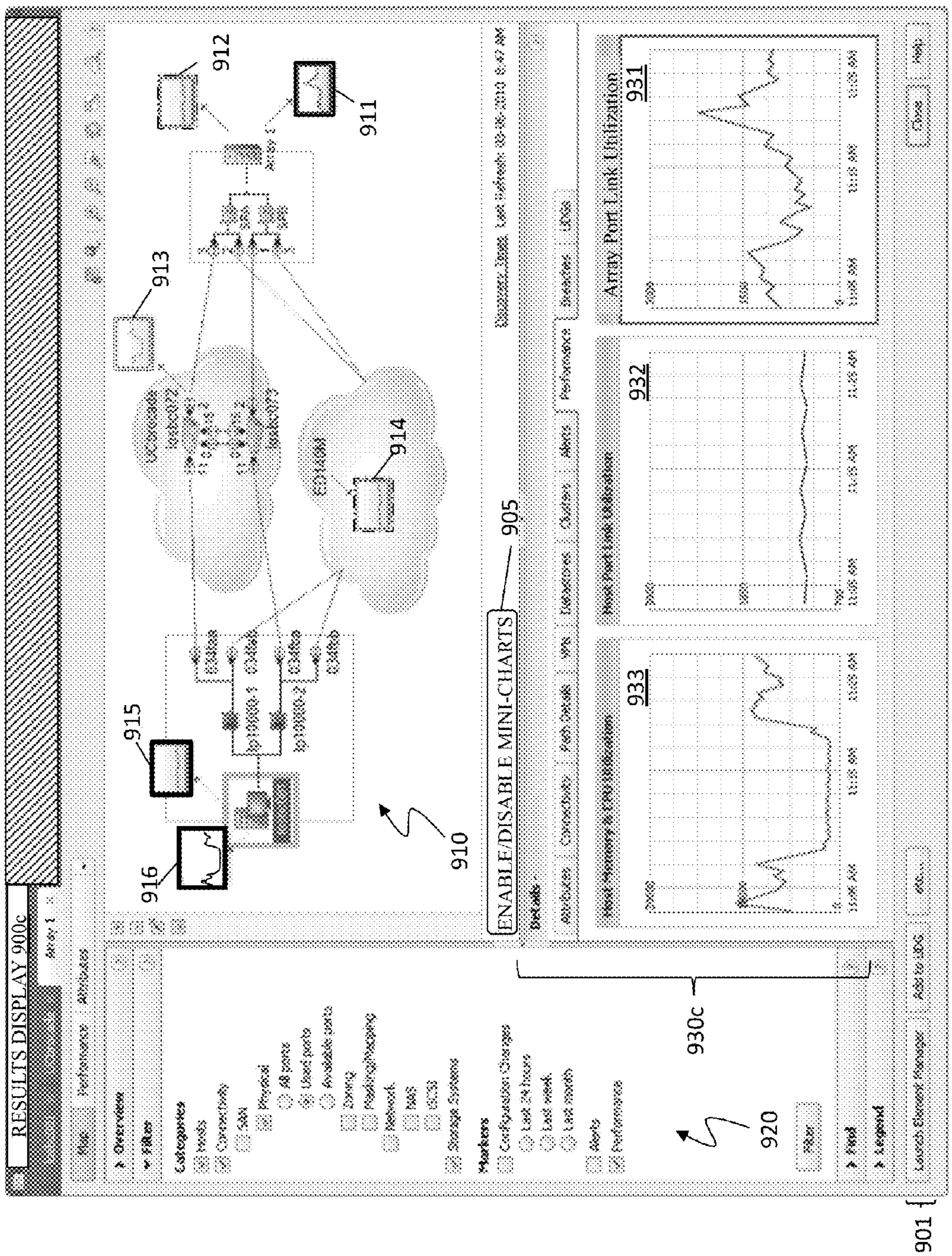

RESULTS DISPLAY 900c
ENABLE/DISABLE MINI-CHARTS
Array Port Link Utilization
901
905
910
911
912
913
914
915
916
920
930c
931
932
933

FIG. 18

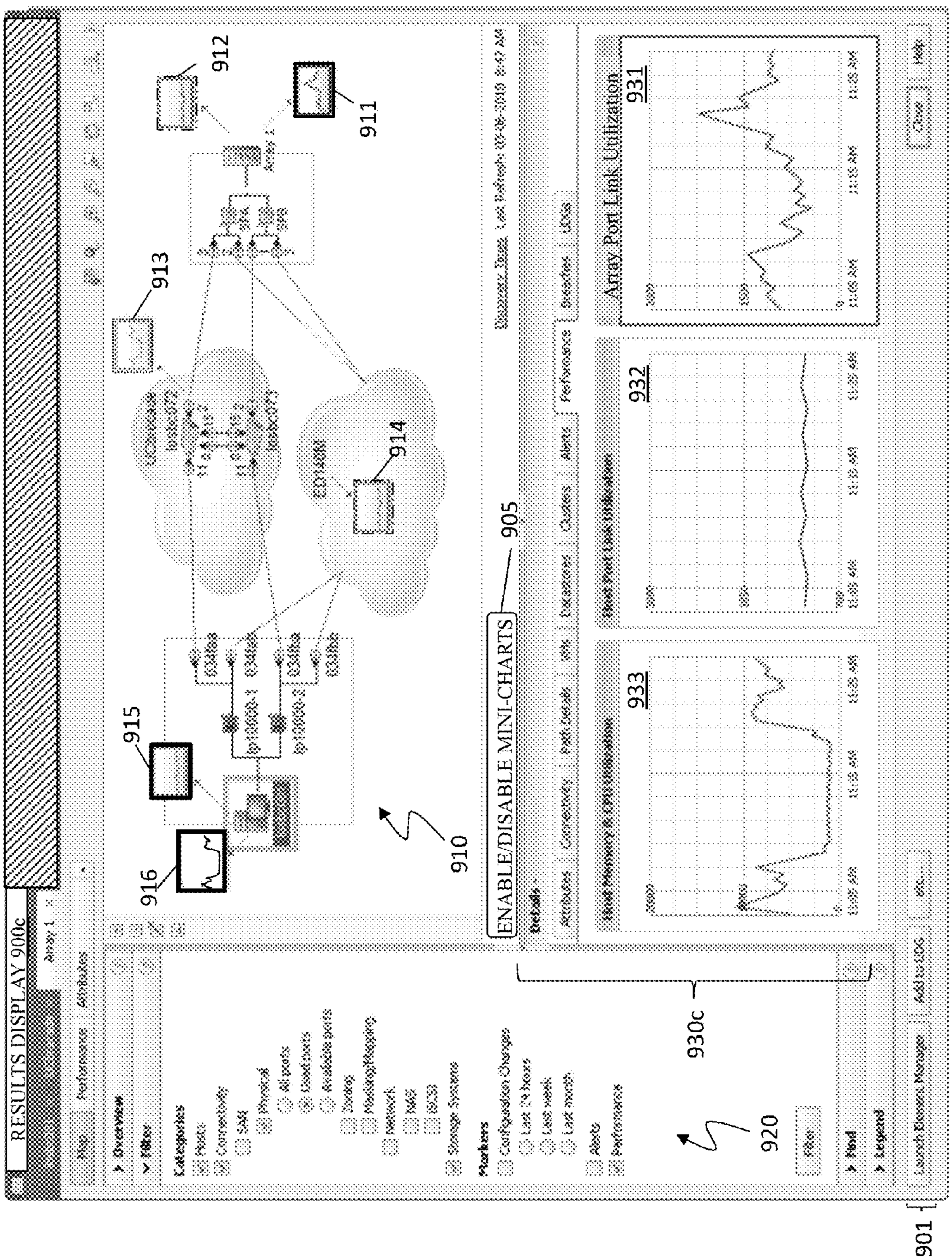

RESULTS DISPLAY 900c
ENABLE/DISABLE MINI-CHARTS
Array Port Link Utilization
901
905
910
911
912
913
914
915
916
920
930c
931
932
933

FIG. 19

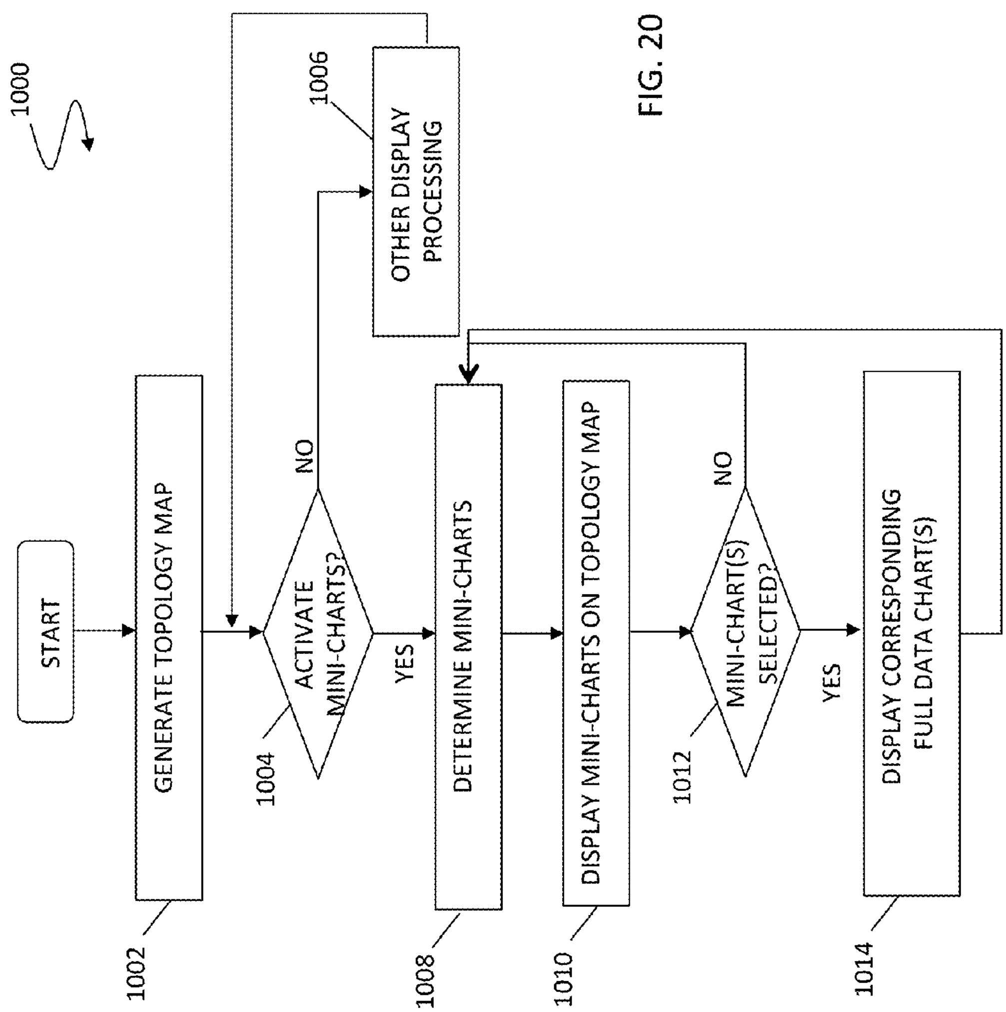

1000
START
GENERATE TOPOLOGY MAP
1002
ACTIVATE MINI-CHARTS?
1004
NO
YES
OTHER DISPLAY PROCESSING
1006
DETERMINE MINI-CHARTS
1008
DISPLAY MINI-CHARTS ON TOPOLOGY MAP
1010
MINI-CHART(S) SELECTED?
1012
NO
YES
DISPLAY CORRESPONDING FULL DATA CHART(S)
1014

FIG. 20

# PATH PERFORMANCE MINI-CHARTS

## TECHNICAL FIELD

This application relates to storage area networks and, more particularly, to the field of performance data collection in a storage area network.

## BACKGROUND OF THE INVENTION

Host processor systems may store and retrieve data using storage devices (also referred to as storage arrays) containing a plurality of host interface units (host adapters), disk drives, and disk interface units (disk adapters). Such storage devices are provided, for example, by EMC Corporation of Hopkinton, Mass. and disclosed in U.S. Pat. No. 5,206,939 to Yanai et al., U.S. Pat. No. 5,778,394 to Galtzur et al., U.S. Pat. No. 5,845,147 to Vishlitzky et al., and U.S. Pat. No. 5,857,208 to Ofek, which are incorporated herein by reference. The host systems access the storage device through a plurality of channels provided therewith. Host systems provide data and access control information through the channels of the storage device and the storage device provides data to the host systems also through the channels. The host systems do not address the disk drives of the storage device directly, but rather, access what appears to the host systems as a plurality of logical volumes. Different sections of the logical volumes may or may not correspond to the actual disk drives.

Characteristics of the storage devices containing the data that has been stored across one or more disk drives and of elements of a storage area network (SAN) coupling the storage devices to one or more hosts may be monitored according to different performance statistics and measures. For example, I/O operations initiated by a host will result in corresponding activity in SAN fabric links, storage array ports and adapters, and storage volumes, measured in I/Os per second and Megabytes per second. Other characteristics may similarly be measured. Such characteristics may be significant factors in managing storage system performance, for example, in analyzing use of lowering access performance versus more expensive higher performance disk drives in a SAN, or by expanding number of SAN channels or channel capacity. Users may balance performance, capacity and costs when considering how and whether to replace and/or modify one or more storage devices or components.

In various circumstances, it may be desirable to collect performance data for objects of a storage system including I/O data paths between one or more hosts and one or more storage devices. Known performance data collection techniques may include a user manually determining and selecting individual managed objects for configuration to collect performance data. For example, when the I/O data paths are changed for the application host, with manual configurations a user would have to determine which managed objects changed within the I/O data paths and update performance data collection jobs accordingly to reflect the changes. Such techniques may be disadvantageously complex and subject to user error. In another example, virtual hosts (e.g., hosts running as guest operating systems or virtual machines (VM's)) may be created in a cluster of physical hosts which rely for I/O transport on previously-created, or dynamically changing, I/O data paths.

Accordingly, it would be desirable to provide a system that may be advantageously used for performance data collection, particularly in connection with the display of the performance data for use in a flexible and efficient manner.

## SUMMARY OF THE INVENTION

According to the system described herein, a method for displaying performance data includes generating a mini-chart. The mini-chart corresponds to a full data chart that displays collected performance data for at least one object of an I/O path. The mini-chart is displayed on a topology map showing objects of the I/O path. Selection of the mini-chart is enabled, in which selection of the mini-chart causes display of the full data chart corresponding to the mini-chart. Displaying the mini-chart on the topology map may include assigning a visual designation of the mini-chart according to a criticality determination. The criticality determination may include determining whether a threshold is reached corresponding to the collected performance data. The threshold may be dynamically set over time based on analytics determined from the collected performance data. The visual designation may be a color of a color coded criticality schema. The method may further include generating the topology map, displaying the topology map on a display, and/or collecting the performance data for the at least one object of the data path.

According further to the system described herein, a non-transitory computer readable medium stores software for displaying performance data. The software includes executable code that generates a mini-chart, wherein the mini-chart corresponds to a full data chart that displays collected performance data for at least one object of an I/O path. Executable code is provided that displays the mini-chart on a topology map showing objects of the I/O path. Executable code is provided that enables selection of the mini-chart, wherein selection of the mini-chart causes display of the full data chart corresponding to the mini-chart. The executable code that displays the mini-chart on the topology map may include executable code that assigns a visual designation of the mini-chart according to a criticality determination. The criticality determination may include determining whether a threshold is reached corresponding to the collected performance data. The threshold may be dynamically set over time based on analytics determined from the collected performance data. The visual designation may be a color of a color coded criticality schema. The software may further include executable code that generates the topology map, executable code that displays the topology map on a display, and/or executable code that collects the performance data for the at least one object of the data path.

According further to the system described herein, a system for displaying performance data includes a display and a performance data collection tool that collects performance data for at least one object of an I/O data path. A non-transitory computer readable medium stores software, executed by at least one processor, for displaying performance data. The software includes executable code that generates a mini-chart, wherein the mini-chart corresponds to a full data chart that displays collected the performance data for the at least one object of the I/O path. Executable code is provided that displays the mini-chart on a topology map showing objects of the I/O path. Executable code is provided that enables selection of the mini-chart, wherein selection of the mini-chart causes display of the full data chart corresponding to the mini-chart. The executable code that displays the mini-chart on the topology map may include executable code that assigns a visual designation of the mini-chart according to a criticality determination. The criticality determination may include determining whether a threshold is reached corresponding to the collected performance data. The threshold may be dynamically set over time based on analytics determined from the collected performance data. The visual designation may be a color of a color coded criticality schema. The software may further include executable code that generates the topology map and/or executable code that displays the topology map on the display.

## BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the system are described with reference to the several figures of the drawings, which are briefly described as follows.

FIG. **1** is a schematic diagram showing a plurality of hosts and a data storage device that may be used in connection with the system described herein.

FIG. **2** is a schematic diagram showing a storage device, memory, a plurality of directors, and a communication module that may be used in connection with the system described herein.

FIG. **3** is a schematic diagram showing a plurality of hosts coupled to a plurality of storage devices via a storage array network (SAN).

FIG. **4** is a schematic illustration of an embodiment of the SAN shown in FIG. **3** including multiple switches providing an I/O path between a host and a storage device in connection with an embodiment of the system described herein.

FIG. **5** is a schematic illustration of a tool, application and/or utility having a user interface that may receive as input path data identification information and workload characteristics of element of the path and output collected performance data metrics according to an embodiment of the system described herein.

FIG. **6** is a schematic illustration showing a changed I/O data path in the SAN that reflects a change from the I/O data path shown in FIG. **4**.

FIG. **7** is a schematic illustration showing an example of a controller of the interface for controlling path performance data collection according to an embodiment of the system described herein.

FIG. **8** is a schematic illustration showing another embodiment of a controller for controlling path performance data collection according to an embodiment of the system described herein.

FIG. **9** is a schematic illustration showing a controller that may be another screen of the interface according to an embodiment of the system described herein.

FIG. **10** is a schematic illustration of a path performance collection settings controller that may be a screen of the user interface according to an embodiment of the system described herein.

FIG. **11** is a schematic illustration showing a results display according to an embodiment of the system described herein.

FIG. **12** is a schematic illustration showing a groups controller that may be provided by the interface according to an embodiment of the system described herein.

FIG. **13** is a schematic illustration showing more specific information in a section concerning a group of hosts according to an embodiment of the system described herein.

FIG. **14** is a flow diagram showing an iteration of path discovery processing and path performance data collection processing according to an embodiment of the system described herein.

FIG. **15** is a more detailed flow diagram showing the processing of the system described herein for the automated identification of changes in I/O data paths and the collection of path performance data thereof according to an embodiment of the system described herein.

FIG. **16** is a schematic illustration showing a results display for an interface of an analytical tool according to an embodiment of the system described herein.

FIG. **17** is a schematic illustration showing, as a results display, display of a full data chart following selection by the user of a mini-chart of the display from FIG. **16** according to an embodiment of the system described herein.

FIG. **18** is a schematic illustration showing, as a results display, display of full data charts following selection by the user of an object of the display from FIG. **16** according to another embodiment of the system described herein.

FIG. **19** is a schematic illustration showing, as a results display, display of full data charts following customized selection by the user of elements of the display from FIG. **16** according to another embodiment of the system described herein.

FIG. **20** is a flow diagram showing performance data display processing using mini-charts according to an embodiment of the system described herein.

## DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS

FIG. **1** is a schematic diagram **20** showing a plurality of hosts **22***a*-**22***c* coupled to a data storage device **24** that may be used in connection with an embodiment of the system described herein. The data storage device **24** includes a memory **26** that facilitates operation of the storage device **24**, as further described elsewhere herein. The data storage device also includes a plurality of host adapters (HA's) **28***a*-**28***c* that handle reading and writing of data between the hosts **22***a*-**22***c* and the storage device **24**. Although the diagram **20** shows each of the hosts **22***a*-**22***c* coupled to each of the HA's **28***a*-**28***c*, it will be appreciated by one of ordinary skill in the art that one or more of the HA's **28***a*-**28***c* may be coupled to other hosts. In an embodiment, the storage device **24** may be a Symmetrix storage device and/or a CLARiiON storage device produced by EMC Corporation of Hopkinton, Mass.

In an embodiment, the storage device **24** may include one or more remote adapter units (RA's) **32***a*-**32***c*. An RA may be used, for example, in connection with a remote data facility (RDF) product produced by EMC Corporation, may be used to copy data from one storage device to another. For example, if a host writes data to a first storage device (e.g., a local storage device), it may be desirable to copy that data to a second storage device provided in a different location (e.g., a remote storage device). The RA's **32***a*-**32***c* are coupled to a remote link **40** and are similar to the HA's **28***a*-**28***c*, but are used to transfer data between the storage device **24** and other storage devices that are also coupled to the remote link **40**. The storage device **24** may be coupled to additional RDF links (not shown) in addition to the remote link **40**. For further discussion of RDF and the use thereof in data recovery and storage techniques, see, for example, U.S. Pat. No. 5,742,792 to Yanai, et al., entitled "Remote Data Mirroring" and U.S. Pat. No. 7,779,291 to Yoder et al., entitled "Four Site Triangular Asynchronous Replication," which are incorporated herein by reference.

The storage device **24** may also include one or more disks **36***a*-**36***c*, each containing a different portion of data stored on the storage device **24**. Each of the disks **36***a*-**36***c* may be coupled to a corresponding one of a plurality of disk adapter units (DA) **38***a*-**38***c* that provides data to a corresponding one of the disks **36***a*-**36***c* and receives data from a corresponding one of the disks **36***a*-**36***c*. The disks **36***a*-**36***c* may include any appropriate storage medium or mechanism, including hard disks, solid-state storage (flash memory), etc. Note that, in some embodiments, it is possible for more than one disk to be serviced by a DA and that it is possible for more than one DA to service a disk. It is noted that the term "data" as used herein may be appropriately understood, in various embodiments, to refer to data files, extents, blocks, chunks and/or other designations that indicate a unit, segment or collection of data.

The logical storage space in the storage device **24** that corresponds to the disks **36***a*-**36***c* may be subdivided into a plurality of volumes or logical devices. The logical devices may or may not correspond to the physical storage space of the disks **36***a*-**36***c*. Thus, for example, the disk **36***a* may contain a plurality of logical devices or, alternatively, a single logical device could span both of the disks **36***a*, **36***b*. The hosts **22***a*-**22***c* may be configured to access any combination of logical devices independent of the location of the logical devices on the disks **36***a*-**36***c*. A device, such as a logical device described above, has a size or capacity that may be expressed in terms of device geometry. The device geometry may include device geometry parameters regarding the number of cylinders in the device, the number of heads or tracks per cylinder, and the number of blocks per track, and these parameters may be used to identify locations on a disk. Other embodiments may use different structures.

One or more internal logical data path(s) exist between the DA's **38***a*-**38***c*, the HA's **28***a*-**28***c*, the RA's **32***a*-**32***c*, and the memory **26**. In some embodiments, one or more internal buses and/or communication modules may be used. In some embodiments, the memory **26** may be used to facilitate data transferred between the DA's **38***a*-**38***c*, the HA's **28***a*-**28***c* and the RA's **32***a*-**32***c*. The memory **26** may contain tasks that are to be performed by one or more of the DA's **38***a*-**38***c*, the HA's **28***a*-**28***c* and the RA's **32***a*-**32***c* and a cache for data fetched from one or more of the disks **36***a*-**36***c*. Use of the memory **26** is further described elsewhere herein in more detail. The storage device **24** may be provided as a stand-alone device coupled to the hosts **22***a*-**22***c* as shown in FIG. **1** or, alternatively, the storage device **24** may be part of, and/or otherwise coupled to, a storage area network (SAN) that may include a plurality of other storage devices as well as switches, routers, network connections, etc., as further discussed elsewhere herein.

FIG. **2** is a schematic diagram **50** illustrating an embodiment of the storage device **24** where each of a plurality of directors **52***a*-**52***c* are coupled to the memory **26**. Each of the directors **52***a*-**52***c* may represent one of the HA's **28***a*-**28***c*, RA's **32***a*-**32***c*, and/or DA's **38***a*-**38***c*. In an embodiment disclosed herein, there may be up to sixty four directors coupled to the memory **26**. Of course, for other embodiments, there may be a higher or lower maximum number of directors that may be used.

The diagram **50** also shows an optional communication module (CM) **54** that provides an alternative communication path between the directors **52***a*-**52***c*. Each of the directors **52***a*-**52***c* may be coupled to the CM **54** so that any one of the directors **52***a*-**52***c* may send a message and/or data to any other one of the directors **52***a*-**52***c* without needing to go through the memory **26**. The CM **54** may be implemented using conventional MUX/router technology where a sending one of the directors **52***a*-**52***c* provides an appropriate address to cause a message and/or data to be received by an intended receiving one of the directors **52***a*-**52***c*. Some or all of the functionality of the CM **54** may be implemented using one or more of the directors **52***a*-**52***c* so that, for example, the directors **52***a*-**52***c* may be interconnected directly with the interconnection functionality being provided on each of the directors **52***a*-**52***c*. In addition, a sending one of the directors **52***a*-**52***c* may be able to broadcast a message to all of the other directors **52***a*-**52***c* at the same time.

In some embodiments, one or more of the directors **52***a*-**52***c* may have multiple processor systems thereon and thus may be able to perform functions for multiple directors. In some instances, at least one of the directors **52***a*-**52***c* having multiple processor systems thereon may simultaneously perform the functions of at least two different types of directors (e.g., an HA and a DA). Furthermore, in some embodiments, at least one of the directors **52***a*-**52***c* having multiple processor systems thereon may simultaneously perform the functions of at least one type of director and perform other processing with the other processing system. In addition, the memory **26** may be a global memory in which all or at least part of the global memory may be provided on one or more of the directors **52***a*-**52***c* and shared with other ones of the directors **52***a*-**52***c*. The memory **26** may be part of a global memory distributed across the processor systems of more than one storage device and accessible by each of the storage devices.

Note that, although specific storage device configurations are disclosed in connection with FIGS. **1** and **2**, it should be understood that the system described herein may be implemented on any appropriate platform. Thus, the system described herein may be implemented using a platform like that described in connection with FIGS. **1** and **2** or may be implemented using a platform that is somewhat or even completely different from any particular platform described herein.

A storage area network (SAN) may be used to couple one or more host devices with one or more storage devices in a manner that allows reconfiguring connections without having to physically disconnect and reconnect cables from and to ports of the devices. A storage area network may be implemented using one or more switches to which the storage devices and the host devices are coupled. The switches may be programmed to allow connections between specific ports of devices coupled to the switches. A port that can initiate a data-path connection may be called an "initiator" port while the other port may be deemed a "target" port.

FIG. **3** is a schematic illustration **80** showing a storage area network (SAN) **60** providing a SAN fabric coupling a plurality of host devices (H1-HN) **22***a-c* to a plurality of storage devices (SD1-SDN) **24***a-c*. Each of the devices **22***a-c*, **24***a-c* may have a corresponding port that is physically coupled to switches of the SAN fabric used to implement the storage area network **60**. The switches may be separately programmed by one of the devices **22***a-c*, **24***a-c* or by a different device (not shown). Programming the switches may include setting up specific zones that describe allowable data-path connections (which ports may form a data-path connection) and possible allowable initiator ports of those configurations. For example, there may be a zone for connecting the port of the host **22***a* with the port of the storage device **24***a*. Upon becoming activated (e.g., powering up), the host **22***a* and the storage device **24***a* may send appropriate signals to the switch(es) of the storage area network **60**, and each other, which then allows the host **22***a* to initiate a data-path connection between the port of the host **22***a* and the port of the storage device **24***a*. Zones may be defined in terms of a unique identifier associated with each of the ports, such as such as a 64-bit world-wide port name (WWPN).

In various embodiments, the system described herein may be used in connection with performance data collection for data migration and/or data mirroring techniques using a SAN. Data transfer among storage devices, including transfers for data migration and/or mirroring functions, may involve various data synchronization processing and techniques to provide reliable protection copies of data among a source site and a destination site. In synchronous transfers, data may be transmitted to a remote site and an acknowledgement of a successful write is transmitted synchronously with the completion thereof. In asynchronous transfers, a data transfer process may be initiated and a data write may be acknowledged before the data is actually transferred to directors at the remote site. Asynchronous transfers may occur in connection with sites located geographically distant from each other. Asynchronous distances may be distances in which asynchronous transfers are used because synchronous transfers would take more time than is preferable or desired. Examples of data migration and mirroring products includes Symmetrix Remote Data Facility (SRDF) products from EMC Corporation.

For further discussion of techniques involving the configuration and use of storage area networks, including virtual storage area networks, references is made, for example, to U.S. Pat. No. 8,028,062 to Wigmore et al., entitled "Non-Disruptive Data Mobility Using Virtual Storage Area Networks With Split Path Virtualization," which is assigned to EMC Corporation and is incorporated herein by reference, that discloses techniques for the creation of a SAN centric storage virtualization layer that allows data mobility and migration without disruption to one or more hosts servers attached to the SAN.

FIG. **4** is a schematic illustration **82** showing multiple SAN switches of a SAN, like that of FIG. **3**, that may be used in connection with an embodiment of the system described herein. In the illustrated embodiment, the SAN is shown with two switches, switch **61** (SW1) and switch **62** (SW2), that are used in connection with an I/O data path **70** from the host **22***a* to the storage device **24***a*. In various embodiments, the switches **61**, **62** may include physical and/or logical devices. Although two switches are shown, more than two switches and/or other appropriate elements of a SAN fabric may be used in connection with the providing of I/O data paths from one or more of the hosts **22***a-c* to one or more of the storages devices **24***a-c* in connection with path performance data collection according to the system described herein.

The selection and/or identification of the I/O path **70** may be performed according to multiple selection factors and using known path selection techniques. Reference is made, for example, to U.S. Pat. No. 7,688,753 to Zimran et al., entitled "Selection of a Data Path Based on One or More Performance Characteristics of a Computer System," which is assigned to EMC Corporation and is incorporated herein by reference and which discloses techniques for data path selection based on performance characteristics of a computer system using a path selection module. Reference is also made to U.S. Pat. No. 6,434,637 to D'Errico, entitled "Method and Apparatus for Balancing Workloads Among Paths in a Multi-Path Computer System Based on the State of Previous I/O Operations," which is assigned to EMC corporation and is incorporated herein by reference and which discloses techniques for selecting one of at least two I/O data paths for transmission of the next I/O operation based upon a state of previously assigned I/O operations queued for transmission over the I/O paths.

FIG. **5** is a schematic illustration of an tool, application and/or utility **100**, having a user interface **110**, that may receive as input path data identification information and performance indicators for workload characteristics of elements of the path and output collected performance data metrics according to an embodiment of the system described herein. Workload characteristics may include for each configuration item (CI) of the I/O path from a host to a storage device, through a SAN, such as the average number of I/Os per unit time (e.g., seconds), the write percentage and/or the average amount of data per unit time (e.g., number of MB per second), among other appropriate characteristics and performance indicators. The user interface **110** of the tool **100** may allow configuration by a user in connection with turning on and off data collection for multiple I/O paths, as further discussed elsewhere herein. The user interface **110** of the tool **100** according to the system described may then display and/or otherwise output path data performance measures and statistics.

In various embodiment, the tool **100** may be an application installed on an application host or other computer providing SAN administration and/or management functionality and/or may be installed on one or more of the hosts **22***a-c* coupled to the SAN. In an embodiment, the tool **100** may include a ProSphere® product produced by EMC Corporation that provides storage resource management functionality. It is noted that statistics used by the tool **100** according to the system described herein may be gathered by the tool itself and/or may be obtained from other sources, such as, for example, data obtained from products produced by EMC Corporation including, the EMC Workload Analyzer (WLA), the Symmetrix Performance Analyzer (SPA)® and/or the Symmetrix CLI statistics collection daemon (STP), among other possible collection devices, applications and/or tools. Reference is made, for example, to U.S. Pat. No. 6,622,221 to Zahavi, entitled "Workload Analyzer and Optimizer Integration," which is assigned to EMC Corporation and is incorporated herein by reference and which discloses techniques used in connection with evaluating the performance of proposed device swap plans in accordance with past performance data collected. Additionally, the system described herein may be used in connection with the systems and methods disclosed in U.S. patent application Ser. No. 12/807,943 to Colon et al., filed Sep. 17, 2010, also assigned to EMC Corporation, entitled "Techniques for Identifying Devices Having Slow Response Times," which is incorporated herein by reference and which provides techniques for identifying one or more data storage volumes, such as one or more logical volumes, exhibiting a performance problem, such as long response times.

The tool **100** according to the system described herein provides for controlled tuning performance data collection through a single application control. In an embodiment, performance data collection may be turned on or off from the application host running the tool **100** via the user interface **110**. The tool **100** may automatically (e.g., without user intervention) update performance data collection characteristics as the application host I/O data path changes according to user controlled settings but without requiring further user intervention during the updating. In various embodiments, the tool may update continuously and/or at specified intervals. Turning on path performance data collection on the application host via the user interface **110** may automatically set up synchronized performance data collection for all managed objects within an I/O data path.

A data I/O path, like the data I/O path **70**, may be made up of managed objects from the application host, such as host **22***a*, though multiple switches **61**, **62** in the SAN fabric **60** down to the storage device **24***a* to which the application host (host **22***a*) is connected (see FIG. **4**). Over time, as the components of the SAN change (e.g., host adapter gets replaced, switch ports are changed and/or storage devices get swapped out) the system described herein may automatically determine what has changed for any I/O data path for the application host and adjust what performance data is to be collected and may ensure collection continues to be synchronized. Such functionality may advantageously be used for troubleshooting performance issues for an application from an end-to-end perspective.

FIG. **6** is a schematic illustration **84** showing a changed I/O data path **72** in the SAN **60** that reflects a change from the I/O data path **70** shown in FIG. **4**. A change in the I/O data path of the host **22***a* is shown schematically in which the I/O data path **72** now includes switch **61** (SW1) and switch **63** (SW3), instead of switch **62** (SW2), and a storage device has been swapped such that I/O data path of the host **22***a* is now includes the storage device **24***b* (SD2) rather than storage device **24***a* (SD1). As further discussed herein, the changes to the I/O path may include, for example, changes to host devices, switches, switch ports, storage devices and/or device ports, among other suitable I/O data path element changes. The tool **100**, according to the system described herein, may automatically determine the changes in the I/O data path **72** and adjust the data performance metrics being collected according to the new elements of the I/O data path **72** without requiring any user intervention.

FIG. **7** is a schematic illustration showing an example of a controller **200** of the interface **110** according to an embodiment of the system described herein. The controller **200** may be a screen of the interface **110** and provides data path discovery and performance data collection control functionality in connection with the tool **100**. Multiple elements of I/O data paths, such as the I/O data path **70** or the I/O data path **72**, may be discovered according to the system described herein in accordance with techniques discussed elsewhere herein. The elements, shown in header section **210**, may include discovered hosts, switches, fabrics, arrays, and groups/clusters. The particular header of section **210** shown in the figure corresponds to discovered hosts **212** which may provide an indication of the discovery of complete I/O data paths from one or more hosts through the SAN and elements thereof to one or more storage devices or arrays.

Specifically, section **220** details multiple I/O data paths that have been discovered for multiple hosts. Information of the I/O data paths identifies the discovered hosts, whether the hosts are virtual (e.g., running as guest operating system or a virtual machine (VM)) or not, the hosts' IP addresses, operating systems and versions thereof, and whether the host is in a group or cluster. In connection with the system described herein, column **222** identifies whether data path performance collection has been activated and column **224** identifies when the last successful discovery process performed to identify the hosts and I/O data paths. In an embodiment, the discovery process may be performed automatically, for example, at periodic scheduled intervals. In another embodiment, a user may also use the interface **110** to manually provide for a discovery process in addition to scheduled discovery processes, for example, by activating the Discover button **231** in the section **230** further discussed below.

Section **230** provides for control by a user using the interface **110** of the discovery and path performance data collection processes. As noted above, the Discover button **231** may be used by a user to manual activate a I/O data path discovery process; however, the system described herein may further operate with automatic discovery scans. For any discovered host I/O data path, the interface provides for a single-click control interface to turn on or off path data collection processing for particular I/O data path(s). This is illustrated with the Turn On Collection button **232** and the Turn Off Collection button **233** that may be used for any one or more of the I/O data paths for the discovered hosts shown in the section **220**.

In an embodiment, the system described herein also provides for grouping host I/O data paths to allow for consolidated analysis of the I/O data paths with a single click using the interface **110**. This is illustrated by the Add to Groups button **234**, as further discussed elsewhere herein. It is noted that other layouts and configurations for the controller **200**, like that of other interface controller screens discussed elsewhere herein, are possible and may be configured according to particular administrator and system policies and requirements.

FIG. **8** is a schematic illustration showing a controller **200'**, like the controller **200**, in which, for a host entry **240** for host "losbc62", path performance data collection has been turned on, as shown by the indicator **242**, according to an embodiment of the system described herein. In various embodiments, path performance data collection may be turned on by selecting the desired host and clicking on the Turn ON Collection button **232** and/or, alternatively, the indicator **242** may provide for a toggling action between ON and OFF by clicking directly on the indicator **242**. When activated, path performance collection may occur for every I/O data path of the host **240**, thereby the collection may be synchronized for all elements of the I/O data paths to collect statistics for the elements at the same time. Settings for path performance collection may be controlled by a default settings. For example, the intervals between collection scans may be subject to a default setting. For example, the interval may be 5 minutes, but may be set to any desirable interval. Settings for a specific host may be controlled via the interface **110** by clicking on a Settings link or button **244** for each discovered host for which path performance collection is activated that will allow the user to view and adjust settings from a settings controller, as further discussed elsewhere herein. After path performance collection is activated for at least one host, results of the data collection for I/O data paths of the host may be viewed by clicking on a Results button **235**, as further discussed elsewhere herein.

FIG. **9** is a schematic illustration showing a controller **300** that may be another screen of the interface **110** according to an embodiment of the system described herein. The controller **300** shows identification of discovered arrays/storage devices of a SAN, similar to the display of discovered hosts shown in connection with interface screens of the controllers **200**, **200'**. It is noted that screens similar to that described for the controller **300** may be provided for other discovered elements including discovered switches and fabrics of the SAN, as illustrated by the tabs in section **310**. Section **320** shows discovered arrays that have been discovered by one or more discovery scans. In an embodiment, the discovery process may be performed automatically, for example, at periodic scheduled intervals. In another embodiment, a user may also use the interface **110** to manually provide for a discovery process in addition to scheduled discovery processes, for example, by activating the Discover button **331** in section **330** further discussed below.

The section **320** provides various information concerning discovered arrays including name, vendor, model, microcode and time of last update. Additionally, column **324** shows the Discovery state or status of the arrays. For example, a successful discovery may indicate that a particular array has been identified and all relevant information for inclusion in an I/O data path identified, whereas a failed discovery may indicate that certain information from the particular array has not been determined by the last discovery scan. The system may attempt to resolve failures with periodic scans. A status of "Running" may indicate that the array is in an I/O data path for which performance data is currently being collected. Column **322** shows whether path performance collection has been turned on or off for the array. For example, in the illustration, for the array entry **340** for "000194900143," the path performance collection indicator **342** shows that path performance collection is turned on for the array, thereby the array is in an I/O data path for which performance data is being collected. For example, the array **340** may be in one or more of the I/O data paths for the host losbc62 (see FIGS. **7** and **8**) for which collection of path performance data has been turned on.

A settings link/button **344** may be used to identify the settings and other collection information, such as identification of the I/O data path, for the array **340**, as further discussed elsewhere herein. Buttons **332** and **333** of the section **330** may be used to turn performance data collection on or off for a particular array. This level of control may enable problem identification in particular elements (arrays, switches, fabric etc.) of an I/O data path. A results button **335** may be used to view displayed results of the performance data collection, as further discussed elsewhere herein.

FIG. **10** is a schematic illustration of a path performance collection settings controller **400** that may be a screen of the user interface **110** according to an embodiment of the system described herein. In the figure, the settings for the path performance collection for the host losbc62 are being illustrated. Section **410** shows the schedule for the automated "smart" collection of performance data for all I/O data paths for host losbc62. Section **420** enables selection and viewing of collection setting information for particular elements of the I/O data paths of the indicated host, including but not limited to workload and performance characteristics such as CPU utilization, memory utilization for the host and IOps (I/O in Mb per sec), response time in ms, throughput in Kbps, and queue length for host devices. Other elements for which information may be obtained include the switches and arrays, as shown in section **420**. Section **430** shows buttons that allow the user to edit settings of the path performance data collection, among other control functionalities.

FIG. **11** is a schematic illustration showing a results display **500**, for example, after clicking on the results button **235** according to an embodiment of the system described herein. The results display **500** may include a graphical section **510** that shows a visual representation of an I/O data path for the selected host, in the illustrated case, for host losbc62. For example, the section **510** graphical displays the host **512**, coupled via SAN switches **514**, to one or more storage devices/arrays **516**. Section **520** may display map details of the I/O data paths, for example performance data for particular elements of the I/O data paths in graph form **522**, **524**, **526** as well as in text or tabulated form **528**. The performance measures displayed may include those discussed elsewhere herein, including workload and performance characteristics such as CPU utilization, memory utilization for the host and IOps (I/O in Mb per sec), response time in ms, throughput in KBps, and queue length for host devices, switches, arrays etc., among other appropriate measures.

Section **530** indicates that multiple types of detail and performance measures may be displayed in various forms for the application host, including features corresponding to the I/O data path attributes, performance, capacity, alerts, connectivity, path details, virtual machine (VM) information, data stores, configuration changes, discovery details and group details. A link button **532** may be provided to view performance collection settings. Additionally, portion **534** indicates that historical or past performance data collection may be maintained by the system. For example, a user may view past performance data collection from the prior day, prior week, prior month and/or any other customizable date range.

FIG. **12** is a schematic illustration showing a groups controller **600** that may be provided by the interface **110** according to an embodiment of the system described herein. The group controller **600** enables the selection, creation and configuring of groups of elements in I/O data paths according to the system described herein. Groups may be defined using default settings for the entire group (e.g., Groups) and/or may be configurable with specific collection settings within a group (e.g., Smart Groups). Section **610** shows the identification of various group types and subsets thereof. Section **620** shows specific information concerning selected groups and may include information for groups of hosts, arrays, fabrics, switches etc. of the I/O data paths. Column **622** shows the indicators for whether path performance collection is turned on or off for particular groups. In the illustrated embodiment, an indicator **642** shows that path performance collection is turned on for a group of hosts **640**. Section **630** shows buttons that may be used to create and delete groups and smart groups according to configurations by the user. Information concerning groups may also be shared and unshared and imported and exported, as shown by buttons in the section **630**. It is noted that group settings may be created and/or shared among groups of varying geographical regions (e.g., Boston, Saint Louis, New York etc.).

FIG. **13** is a schematic illustration showing more specific information in a section **620'** concerning a group of hosts **650** according to an embodiment of the system described herein. Hosts 1-12 **650** are shown in the illustrated screen window and it is noted that the turning of path performance collection on for the entire group in FIG. **12** has turned on path performance collection for the I/O data paths of each of the Hosts 1-12 **650** as shown by the indicators **652** in accordance with the system described herein. Section **630'** shows Turn ON Collection and Turn OFF Collection buttons that may be used to turn on or off collections for individual ones of the selected host group. Other configurations and groups designations may be specified by a user according to desired administrator and/or system requirements.

FIG. **14** is a flow diagram **700** showing an iteration of path discovery processing and path performance data collection processing according to an embodiment of the system described herein. At a step **702**, a discovery process is performed to identify elements of a SAN through which one or more I/O data paths of one or more host exist. I/O data paths may exist from one or more hosts to one or more storage arrays or devices via switches and/or other elements of the SAN. In an embodiment, the discovery process may be automated to occur continuously and/or at scheduled intervals. Accordingly, the process may automatically identify changes to I/O data paths that may occur as a result of changes to the elements of the SAN without requiring user intervention. In this way, the system is self-tuning to respond to the changes in I/O data paths without requiring that the user have information or knowledge concerning the I/O data path changes. Settings controlling the automation may be set and/or otherwise controlled via a user interface, as further discussed elsewhere herein.

After the step **702**, processing proceeds to a step **704** where the discovered elements from the discovery process may be displayed on the user interface. The discovered elements may include one or more hosts from which one or more I/O data paths extend. After the step **704**, processing proceeds to a step **706** where the interface receives user input to turn on performance data collection for the one or more of the discovered hosts to collect performance data for the I/O data paths thereof. In an embodiment, the input is a single click on a performance data collection indicator and/or an button to turn on collection. After the step **706**, processing proceeds to a step **708** where performance data for I/O data paths of the one or more selected hosts is collected. After the step **708**, processing proceeds to a test step **710** where it is determined whether the results of the collection are to be displayed. For example, whether the user has requested the interface to display the results. If not then processing of the iteration of performance data collection is complete. If the results are to be displayed, then processing proceeds to a step **712** where the collection results are displayed on the interface. After the step **712**, processing of the iteration is complete.

FIG. **15** is a more detailed flow diagram **800** showing the processing of the system described herein for the automated identification of changes in I/O data paths and the collection of path performance data thereof according to an embodiment of the system described herein. At a step **802**, an path performance data collection application according to the system described herein is executed. After the step **802**, processing proceeds to a step **804** where discovery processing is performed to discover elements of one or more storage area networks, including hosts and storage arrays, according to the system described herein. After the step **804**, processing proceeds to a test step **806** where it is determined whether path performance collection processing has been activated for one or more of the discovered hosts. In an embodiment, path performance collection processing may be activated, for example, via an interface by an user clicking, with a single click, on a path performance collection button or indicator.

If no path performance collection processing has been activated at the test step **806**, then processing proceeds to a test step **808** where it is determined whether another discovery scan is to occur according to the scheduled intervals for discovery scans for automatically updating the discovery processes according to the system described herein. Discovery scans may be scheduled through the interface. If it is time for a scheduled discovery scan, then processing proceeds back to the step **804**. Otherwise, processing proceeds from the test step **808** to a test step **810** where it is determined whether any performance data collection processing has been activated by a user. If not then processing proceeds back to the test step **808**. In this way, the system described herein provides for automated and continuous discovery scanning while a path performance data collection application is active.

If at the test step **810**, and, likewise at the test step **806**, it is determined that path performance collection processing has been activated via the interface, in a manner as discussed elsewhere herein, then processing proceeds to a step **812** where path performance data is collected for all I/O paths of one or more discovered hosts according or other objects to the selections made via the interface. After the step **812**, processing proceeds to a test step **814** where it is determined whether path performance data collection is to continue. For example, it is determined whether a user has turned off collection for the selected hosts via the interface. If path performance data collection is not to continue as determined at the test step **814** (e.g. the user has clicked on the turn off collection button/indicator) then processing proceeds back to the test step **808** where it is again determined whether another scheduled discovery scan is to occur to update the discovered elements, as discussed above.

If, at the test step **814**, it is determined that path performance data collection is to continue, then processing proceeds to a test step **816** where it is determined whether another scheduled discovery scan is to occur. If not then processing proceeds back to the step **812** where the system continues to collect path performance data for the I/O data path(s) of the selected host(s). If, at the test step **816**, it is determined that it is time for another scheduled discovery scan, then processing proceeds to a step **818** where the discovery scan is performed. After the step **818**, processing proceeds to a test step **820** where it is determined whether any of the I/O data paths of the selected host(s) have changed. If not, then processing proceeds back to the step **812** where the system continues to collect path performance data for the current I/O data path(s) of the selected host(s). If, however, at the test step **820**, it is determined that one or more of the I/O data paths have changed, then processing proceeds to a step **822** where the I/O data path information is updated automatically by the system described herein and path performance data for the changed I/O data paths is collected. After the step **822**, processing proceeds back to the test step **814** where it is determined whether path performance data collection is to continue. Accordingly, the system described herein provides a self-tuning path performance data collection system using a single application control interface that may automatically and continuously update host I/O data path changes without requiring user intervention to detect and process the changes.

It is further noted that the system described herein may be used in connection with simulation of data storage systems for evaluation purposes. For example, I/O data paths of simulated storage system configurations may be evaluated to determine preferred configurations and/or identify potential problems of a possible I/O data path and elements thereof. Suitable data storage system simulation tools that may be used in connection with the system described herein may include systems and methods like that disclosed in U.S. Pat. No. 7,392,360 to Aharoni et al., entitled "Method and System for Capacity Planning and Configuring One or More Data Storage Systems," U.S. Pat. No. 7,292,969 to Aharoni et al., entitled "Method and System for Simulating Performance on One or More Storage Systems," and U.S. patent application Ser. No. 13/065,806 to Smirnov et al., filed Mar. 30, 2011, entitled "Write Pacing Simulation Tool," which are all assigned to EMC Corporation and which are all incorporated herein by reference.

According to another embodiment, the system described herein may provide display results from performance data analyses that present mini-chart overlays on a topology map based on intelligent analytics for components in one or more I/O data paths. The mini-charts may be advantageously used to show criticality of impact to assist a user with incident avoidance and/or to provide fast incident resolution. When launching into the topology map, the user may enable mini-charts and visually see from the charts where a possible performance bottleneck is detected by the analytics. In an embodiment, the mini-charts for the most relevant metrics may be displayed and identified for criticality. In various embodiments, the mini-charts may be colored and/or sized for criticality, among other appropriate visual criticality designations, The criticality visuals may be determined by thresholds, that may be set by a user and/or determined by the system, and may be calculated automatically based on learned base line, maximum line and minimum line operations over set times. A user may manually override a threshold set by the system, if desired.

The mini-charts may represent a small image of a full data chart. By selecting a mini-chart, the user may be shown the larger chart version and/or other details that may enable the user to locate and identify specific performance issues. An I/O data path may be made up of managed objects from an application host through multiple storage switches in the storage fabric down to the storage arrays to which the application host is connected. Performance metrics may be collected and analyzed by the system for selected objects, as discussed elsewhere herein. Events and alerts may be generated that alert the user to one or more conditions. The user may then select a relevant object and see the high level performance map based on the topology, as aided by the mini-charts and analytics described herein.

The system described herein advantageously simplifies the troubleshooting of performance issues for an application from an end-to-end perspective. The system described herein reduces required steps for display of useful performance analytics for a user. The user may simply turn on mini-charts (e.g., with a single click of a button) on the topology map of a selected application host or other object and the system described herein will handle correlation, chart creation, and analytical evaluation of potential bottlenecks and their visualization without requiring further user intervention. Further, the system may advantageously calculate thresholds and base lines based on learned or determined analytics and highlight mini-charts, for example, in colors such as red, green, yellow or other appropriate colors of a color coded criticality schema, to draw attention to main problem areas. In an embodiment, based on use of the mini-charts and resulting identification of problem areas of an I/O path, an alternative I/O path between relevant objects may be determined and selected either manually by a user and/or, in some cases, automatically by the system according to one or more policies.

FIG. **16** is a schematic illustration showing a results display **900** for an interface of an analytical tool, like the interface **110** and tool **100** discussed elsewhere herein, according to an embodiment of the system described herein. In the illustrated embodiment, multiple tabs are shown in connection with obtaining performance data results for particular objects, including hosts, switches and arrays of an I/O path to or from a particular element (e.g., shown for objects and elements identified as: losbc081, UCbrocade, and Array 1). The results shown in the display **900** are for evaluations of an I/O path determined in connection with Array 1. A topology map **910** is shown for objects in the I/O path from the application host (losbc081) through switches of a fabric down to the Array 1. The objects and elements shown in the I/O path may be filtered using controls **920** that, for example, enable filtering of a topology map according to various categories of objects and elements, including hosts, switches or other elements of a network fabric and storage arrays. Other controls **901** of the display **900** may be provided, including a launch element manager control that may enable a user to launch to an interface and/or another application to manage a particular problem object identified according to the system described herein and/or a group button to add one or more objects to a particular group, among other control options.

A control button **905** is shown that may provide for enabling or disabling the display of the min-charts on the topology map. As illustrated, mini-charts have been enabled and multiple mini-charts **911-916** are shown on the topology map **910** and visually presented adjacent to corresponding objects and elements of the I/O path (e.g., the control button **905** has been clicked and mini-charts have been enabled). The mini-charts may be representative of full data charts corresponding to the collected performance data for the objects and elements of the I/O path. In an embodiment, the mini-chart may be a smaller version of the full data chart that visually resembles the full data chart, but which contains less presented data than the full data chart. As discussed elsewhere herein, the mini-charts **911-916** may be visually presented corresponding to thresholds of related data and indicate alerts levels of problem areas in the I/O path. In an embodiment, the mini-charts **911-916** may be colored for criticality according to a color coded criticality schema. The multiple color aspect of the mini-charts is illustrated in the figure by different styles of dashed-line borders of the mini-charts **911-916**. A details display segment **930** is shown that may provide performance information and other detailed information, including, for example, information of attributes, connectivity, path details, VMs, data stores, clusters, alerts, breaches and used defined groups (UDG) in connection with the I/O path shown in the topology map **910**.

FIG. **17** is a schematic illustration showing, as a results display **900***a*, display of a full data chart following selection by the user of a mini-chart of the display **900** from FIG. **16** according to an embodiment of the system described herein. The illustrated display **900***a* shows a details display segment **930***a* after a user clicks on or otherwise selects the mini-chart **911** shown for the Array 1 object. The details display segment **930***a* displays, under performance details, the full data chart **931** corresponding to the mini-chart **911**. In the illustrated example, chart **931** shows array port link utilization of the Array 1.

FIG. **18** is a schematic illustration showing, as a results display **900***b*, display of full data charts following selection by the user of an object of the display **900** from FIG. **16** according to another embodiment of the system described herein. The illustrated display **900***b* shows a details display segment **930***b* after a user clicks on or otherwise selects the application host losbc081, which may display all charts corresponding to available mini-charts (e.g., the mini-charts **915** and **916**) for the host losbc081. The details display segment **930***a* displays, under performance details, the full data charts **932** and **933** corresponding to the mini-charts **915** and **916** for losbc081. In the illustrated example, the chart **932** shows host port link utilization for losbc081 and the chart **933** shows host memory and CPU utilization for losbc081.

FIG. **19** is a schematic illustration showing, as a results display **900***c*, display of full data charts following customized selection by the user of elements of the display **900** from FIG. **16** according to another embodiment of the system described herein. The illustrated display **900***c* shows a details display segment **930***c* after a user clicks on or otherwise selects mini-charts **911**, **915** and **916**. The details display segment **930***c* displays, under performance details, the full data charts **931**, **932** and **933** corresponding to the mini-charts **911**, **915** and **916** for Array 1 and losbc081. In the illustrated example, the chart **931** shows array port link utilization of the Array 1, the chart **932** shows host port link utilization for losbc081, and the chart **933** shows host memory and CPU utilization for losbc081. It is noted that any desired selection of mini-charts is possible, and the system described herein thereby enables advantageous customization for a user to select and display one or more of any desired mini-charts to aid in problem resolution for I/O paths in the network topology.

FIG. **20** is a flow diagram **1000** showing performance data display processing using mini-charts according to an embodiment of the system described herein. At a step **1002**, a topology map is generated according to discovery processing performed by the system described herein and based on user configurations and displayed on a results display like that further discussed elsewhere herein. After the step **1002**, processing proceeds to a test step **1004** where it is determined whether display of mini-charts has been activated, for example, by action of a user. If, at the test step **1004**, it is determined that no mini-charts are to be displayed, then processing proceeds to a step **1006** where other performance data display processing, other than that using mini-charts, is provided. After the step **1006**, processing proceeds back to the test step **1004**.

If, at the test step **1004**, it is determined that display of mini-charts has been activated, then processing proceeds to a step **1008** where mini-charts are determined according to the collected performance data, and determined analytics thereof, for relevant objects of an I/O path. As further discussed elsewhere herein, the mini-charts may be representative of full data charts corresponding to collected performance data for the relevant objects of the I/O path, and may be colored and/or otherwise designated according to criticality thresholds. For example, a threshold may be determined corresponding to port link utilization, that, if reached, causes the mini-chart to appear red, or be otherwise colored or displayed, to indicate a potential problem. In this way, the threshold may be set dynamically over time by automatic action of the system described herein based on the analytics determined for the collected performance data. Specifically, one or more thresholds may be set according to determinations of base line system operations, minimum line system operations and maximum line system operations over a particular period of time. After the step **1008**, processing proceeds to a step **1010** where the mini-charts are displayed on the topology map.

After the step **1010**, processing proceeds to a test step **1012** where it is determined whether one or more of the mini-charts have been selected by the user. If not, then processing proceeds back to the step **1008** in may what may be part of refresh processing in which the mini-charts are periodically updated. If, at the test step **1012**, it is determined that the user has selected one or more of the mini-charts (for example, by a single click of a user on a mini-chart enable button), then processing proceeds to a step **1014** where full data charts corresponding to the selected mini-charts are displayed on the results display. After the step **1014**, processing proceeds back to the step **1008** according to the above-noted refresh processing.

Various embodiments discussed herein may be combined with each other in appropriate combinations in connection with the system described herein. Additionally, in some instances, the order of steps in the flowcharts, flow diagrams and/or described flow processing may be modified, where appropriate. Further, various aspects of the system described herein may be implemented using software, hardware, a combination of software and hardware and/or other computer-implemented modules or devices having the described features and performing the described functions. Software implementations of the system described herein may include executable code that is stored in a computer readable medium and executed by one or more processors. The computer readable medium may include a computer hard drive, ROM, RAM, flash memory, portable computer storage media such as a CD-ROM, a DVD-ROM, a flash drive and/or other drive with, for example, a universal serial bus (USB) interface, and/or any other appropriate tangible or non-transitory computer readable medium or computer memory on which executable code may be stored and executed by a processor. The system described herein may be used in connection with any appropriate operating system.

Other embodiments of the invention will be apparent to those skilled in the art from a consideration of the specification or practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with the true scope and spirit of the invention being indicated by the following claims.

What is claimed is:

**1**. A method for displaying performance data, comprising:

generating a mini-chart, wherein the mini-chart corresponds to a full data chart that displays collected performance data for at least one object of an I/O path;

displaying the mini-chart as an overlay on a topology map showing objects of the I/O path, wherein the mini-chart is displayed in a position on the topology map adjacent to the least one object of the I/O path displayed on the topology map, wherein the mini-chart is a smaller image of the full data chart and presents at least a portion of the performance data collected for the least one object of the I/O path but wherein the mini-chart presents less data than the full data chart, and wherein displaying the mini-chart on the topology map includes assigning a color to the mini-chart on the topology map according to a criticality determination and based on a color coded criticality schema; and

enabling selection of the mini-chart, wherein selection of the mini-chart causes display of the full data chart corresponding to the mini-chart.

**2**. The method according to claim **1**, wherein the criticality determination includes determining whether a threshold is reached corresponding to the collected performance data.

**3**. The method according to claim **2**, wherein the threshold is dynamically set over time based on analytics determined from the collected performance data.

**4**. The method according to claim **1**, further comprising:

generating the topology map; and

displaying the topology map on a display.

**5**. The method according to claim **1**, further comprising:

collecting the performance data for the at least one object of the data path.

**6**. The method according to claim **1**, wherein the mini-chart is one of a plurality of mini-charts that are generated and displayed on the topology map, wherein each of the mini-charts corresponds to each of a plurality of full data charts, and wherein each of the plurality of mini-charts are displayed in a color on the topology map according to the criticality determination and the color coded criticality schema.

**7**. The method according to claim **6**, wherein selection of multiple ones of the plurality of the mini-chart causes display of multiple full data charts at a same time on a display.

**8**. A non-transitory computer readable medium storing software for displaying performance data, the software comprising:

executable code that generates a mini-chart, wherein the mini-chart corresponds to a full data chart that displays collected performance data for at least one object of an I/O path;

executable code that displays the mini-chart as an overlay on a topology map showing objects of the I/O path, wherein the mini-chart is displayed in a position on the topology map adjacent to the least one object of the I/O path displayed on the topology map, wherein the mini-chart is a smaller image of the full data chart and presents at least a portion of the performance data collected for the least one object of the I/O path but wherein the mini-chart presents less data than the full data chart, and wherein displaying the mini-chart on the topology map includes assigning a color to the mini-chart on the topology map according to a criticality determination and based on a color coded criticality schema; and

executable code that enables selection of the mini-chart, wherein selection of the mini-chart causes display of the full data chart corresponding to the mini-chart.

9. The non-transitory computer readable medium according to claim **8**, wherein the criticality determination includes determining whether a threshold is reached corresponding to the collected performance data.

10. The non-transitory computer readable medium according to claim **9**, wherein the threshold is dynamically set over time based on analytics determined from the collected performance data.

11. The non-transitory computer readable medium according to claim **8**, wherein the software further comprises:
executable code that generates the topology map; and
executable code that displays the topology map on a display.

12. The non-transitory computer readable medium according to claim **8**, wherein the software further comprises:
executable code that collects the performance data for the at least one object of the data path.

13. The non-transitory computer readable medium according to claim **8**, wherein the mini-chart is one of a plurality of mini-charts that are generated and displayed on the topology map, wherein each of the mini-charts corresponds to each of a plurality of full data charts, and wherein each of the plurality of mini-charts are displayed in a color on the topology map according to the criticality determination and the color coded criticality schema.

14. The non-transitory computer readable medium according to claim **13**, wherein selection of multiple ones of the plurality of the mini-chart causes display of multiple full data charts at a same time on a display.

15. A system for displaying performance data, comprising:
a display; and
a performance data collection tool that collects performance data for at least one object of an I/O data path; and
a non-transitory computer readable medium storing software, executed by at least one processor, for displaying performance data, the software comprising:
executable code that generates a mini-chart, wherein the mini-chart corresponds to a full data chart that displays collected the performance data for the at least one object of the I/O path;
executable code that displays the mini-chart as an overlay on a topology map showing objects of the I/O path, wherein the mini-chart is displayed in a position on the topology map adjacent to the least one object of the I/O path displayed on the topology map, wherein the mini-chart is a smaller image of the full data chart and presents at least a portion of the performance data collected for the least one object of the I/O path but wherein the mini-chart presents less data than the full data chart, and wherein displaying the mini-chart on the topology map includes assigning a color to the mini-chart on the topology map according to a criticality determination and based on a color coded criticality schema; and
executable code that enables selection of the mini-chart, wherein selection of the mini-chart causes display of the full data chart corresponding to the mini-chart.

16. The system according to claim **15**, wherein the criticality determination includes determining whether a threshold is reached corresponding to the collected performance data.

17. The system according to claim **16**, wherein the threshold is dynamically set over time based on analytics determined from the collected performance data.

18. The system according to claim **15**, wherein the software further comprises:
executable code that generates the topology map; and
executable code that displays the topology map on the display.

19. The system according to claim **15**, wherein the mini-chart is one of a plurality of mini-charts that are generated and displayed on the topology map, wherein each of the mini-charts corresponds to each of a plurality of full data charts, and wherein each of the plurality of mini-charts are displayed in a color on the topology map according to the criticality determination and the color coded criticality schema.

20. The system according to claim **19**, wherein selection of multiple ones of the plurality of the mini-chart causes display of multiple full data charts at a same time on a display.

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